North Pleasant Street at Pine Street and Sunderland Road at Montague Road Updated Analysis

Town of Amherst

February 2019



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Section ES

Executive Summary

The Town of Amherst, Massachusetts, is considering potential traffic control improvements at the intersections of North Pleasant Street at Pine Street and Meadow Street and Sunderland Road at Montague Road in North Amherst.

CDM Smith previously evaluated traffic operations and potential traffic control improvements at each intersection in 2015. The 2015 study for the intersection of North Pleasant Street at Pine Street and Meadow Street evaluated three traffic control alternatives:

- Traffic control signal upgrade with signal timing and setting improvements
- Traffic control signal upgrade with added eastbound Meadow Street left turn lane and signal phasing, timing and setting improvements
- Single lane roundabout

Based on the 2013 traffic count data used in the 2015 study, CDM Smith recommended the traffic control signal upgrade with the eastbound Meadow Street left turn lane due to improved operations and reduced vehicle conflicts with the left turn lane and phasing improvements.

The 2015 study for the intersection of Sunderland Road at Montague Road evaluated providing stop control on both Sunderland Road and Montague Road approaches and allowing free flow northbound from the adjacent North Pleasant Street at Pine Street and Meadow Street intersection. The study did not recommend the traffic control improvement due to the potential for driver confusion with an unorthodox traffic control configuration and visibility concerns both at night and in inclement weather.

This new study evaluated the following traffic control options for the intersection of North Pleasant Street at Pine Street and Meadow Street:

- Traffic control signal upgrade with added eastbound Meadow Street left turn lane
- Roundabout

The following traffic control options were considered for the intersection of Sunderland Road at Montague Road:

- Realign Sunderland Road to create a T-type intersection with Montague Road
- Realign Montague Road to create a T-type intersection with Sunderland Road
- 3-Legged Roundabout excludes adjacent plaza driveway from roundabout control
- 4-Legged Roundabout incorporates adjacent plaza driveway into roundabout control



This study used 2017 traffic count data to project traffic volumes to 2018 Existing Conditions and 2038 Future Conditions with and without improvements at each study intersection. The 2017 traffic count data, and therefore the 2018 Existing Condition traffic volumes, showed a different composition of turning movement demand during the Weekday PM peak hour at the intersection of North Pleasant Street at Meadow Street and Pine Street than the 2013 traffic data used in the 2015 report prepared by CDM Smith. The data showed a 3% increase in vehicles traveling through the intersection between the 2013 and the 2018 Existing Conditions traffic volumes, but a 41% increase in turning vehicles along the North Pleasant Street left turn and right turn movements, the Meadow Street right turn movement, and the Pine Street right turn movement.

Although the traffic control signal option with the installation of an exclusive eastbound left turn lane provided the best overall traffic operational performance in the 2015 analysis, the updated analysis indicated that the roundabout option at the intersection of North Pleasant Street at Meadow Street and Pine Street will process the vehicle demand and high turning movement composition at the intersection more efficiently than the traffic control signal option. The roundabout option is anticipated to provide less vehicle delay and smaller vehicle queue lengths. The roundabout option would also have less impact to traffic operations at the adjacent study intersection. The roundabout option, however, would require a westbound right turn bypass lane similar to that installed at the East Pleasant Street and Triangle Street roundabout in order to operate efficiently. The impact to private property to accommodate the roundabout with the requisite westbound right turn slip lane will need to be assessed to determine if the roundabout is fully feasible.

At the intersection of Sunderland and Montague Roads, the 3-legged and 4-legged roundabout options are forecasted to serve all approaches efficiently while the stop-controlled approaches at the T-type intersection options are expected to experience long delays and large vehicle queue lengths. The roundabout flow efficiency at Sunderland Road and Montague Road, however, is contingent upon vehicle queues along the southbound approach at the intersection of North Pleasant Street at Pine Street and Meadow Street processing efficiently without extending into the roundabout. The distance between the 4-legged roundabout and Meadow Street/Pine Street may be slightly larger than the distance between the 3-legged roundabout and Meadow Street/Pine Street. By increasing the distance between the intersections, the available queueing distance for the southbound North Pleasant Street approach is also increased, reducing potential interactions between the intersections. Another added benefit of the 4-legged roundabout is that the adjacent plaza access can be incorporated directly into the roundabout control.

Due to the anticipated traffic operations, access to the private plaza drives, and potentially reduced interactions between the study intersections, CDM Smith recommends a single lane roundabout with a westbound right turn bypass lane at the intersection of North Pleasant Street at Meadow Street and Pine Street complemented by a 4-legged roundabout at the intersection of Sunderland Road at Montague Road which incorporates private plaza access into the roundabout control.



Section 1 Introduction

The Town of Amherst, Massachusetts, has retained CDM Smith to conduct a traffic study to evaluate potential traffic control improvement alternatives at the intersections of North Pleasant Street at Pine Street and Meadow Street and Sunderland Road at Montague Road in North Amherst. The location of the study intersections is depicted on Figure 1-1.

North Pleasant Street at Pine Street and Meadow Street is currently a traffic signal controlled four-legged intersection, while the Y-type Sunderland Road at Montague Road intersection (located less than 200 ft to the north of Pine Street and Meadow Street) is under stop control only on the Montague Road approach.

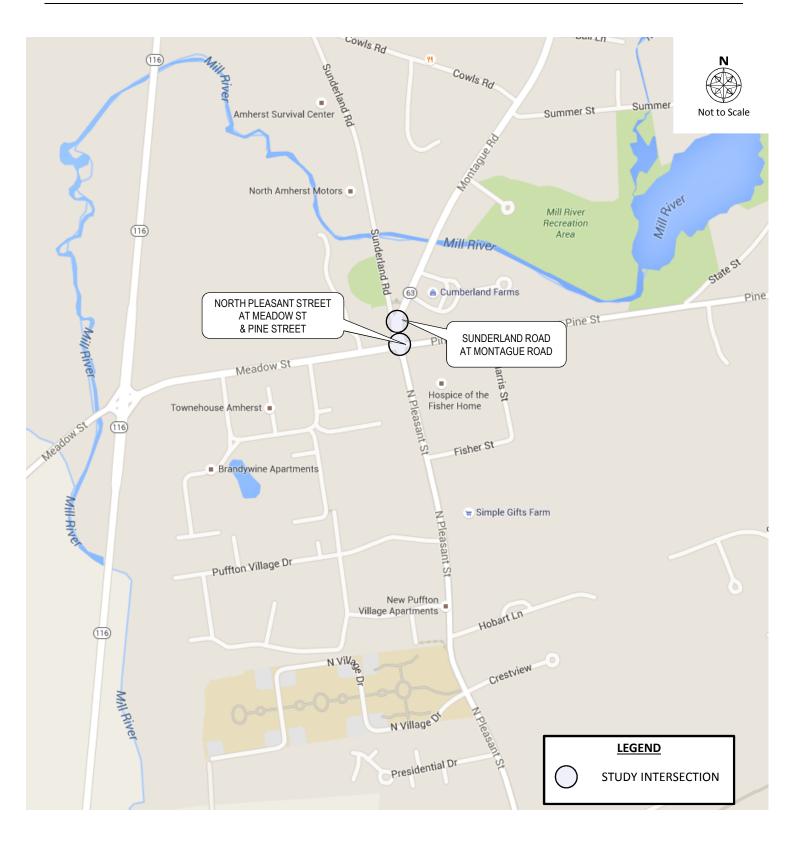
CDM Smith previously completed separate traffic studies to evaluate traffic operations and potential traffic control improvements at each intersection in 2015. The 2015 study for the intersection of North Pleasant Street at Pine Street and Meadow Street evaluated the following traffic control alternatives:

- Alternative 1:
 - Traffic control signal upgrade
 - Signal timing and setting improvements
- Alternative 2:
 - Traffic control signal upgrade
 - Added eastbound Meadow Street left turn lane
 - Signal phasing, timing and setting improvements
- Alternative 3:
 - Single lane roundabout

Based on the data available at that time, CDM Smith recommended Alternative 2 due to improved operations and reduced vehicle conflicts with the left turn lane and phasing improvements.

The 2015 study for the intersection of Sunderland Road at Montague Road evaluated the installation of a stop sign on the Sunderland Road approach to Montague Road. The intersection would allow free flow northbound from the adjacent North Pleasant Street at Pine Street and Meadow Street intersection while providing stop control on both Sunderland Road and Montague Road approaches. The study did not recommend the unorthodox traffic control configuration primarily due to expected violation of driver expectancy leading to driver confusion and potential







safety deficiencies as well as the potential for southbound motorists along Sunderland Road to focus on the upstream traffic signals instead of the approach stop sign control.

This study evaluates multiple permutations of potential traffic control options at each intersection including the installation of a roundabout at one or both. The basic traffic control options evaluated at each intersection are as follows:

- North Pleasant Street at Pine Street and Meadow Street
 - Option 1:
 - o Traffic control signal upgrade
 - o Added eastbound Meadow Street left turn lane
 - Signal Phasing, Timing and Setting Improvements
 - Option 2:
 - Roundabout
- Sunderland Road at Montague Road
 - Option 1:
 - o Realign Sunderland Road to create a T-type intersection with Montague Road
 - Option 2:
 - Realign Montague Road to create a T-type intersection with Sunderland Road
 - Option 3:
 - 3-Legged Roundabout
 - o Roundabout excludes adjacent plaza driveway from roundabout control
 - Option 4:
 - 4-Legged Roundabout
 - Roundabout incorporates adjacent plaza driveway into roundabout control



Section 2

Study Methodology

The traffic impact evaluation of the traffic control alternatives required the following tasks:

- Obtained 2017 existing traffic volume data for Weekday Morning (AM), Weekday Afternoon (PM) and Saturday Midday Peak Period Turning Movement Counts at study intersections.
- Compared 2017 existing traffic volume data to historic 2016, 2013, and 2010 traffic data to
 evaluate regional traffic growth. Based on this comparison, a 1% annual growth rate was
 recommended.
- Developed 2018 Existing Conditions traffic volume network by increasing 2017 traffic data by the 1% annual growth rate.
- Developed year 2018 Build Conditions traffic volumes for all traffic control improvement options based on the re-distribution of traffic volumes anticipated with the intersection reconfigurations.
- Acquired anticipated traffic data from other developments in the vicinity of the study area.
- Developed year 2038 Future No-Build Conditions traffic volumes based on the recommended 1.0% annual growth rate, traffic associated with other developments, and existing traffic volumes.
- Developed year 2038 Future Build Conditions traffic volumes for all traffic control improvement options based on the Future Conditions traffic volumes and the redistribution of traffic volumes anticipated with the intersection reconfigurations.
- Conducted preliminary roundabout analysis for both study intersections to determine likely approach and circulating lane configurations.
- Conducted capacity analyses for the Existing and Future Conditions with and without improvements.
- Evaluated each construction alternative based on the completed analysis.

The construction alternatives evaluated include the following combinations of the aforementioned traffic control options at each intersection:

- Alternative 1: proposed signal at North Pleasant, Pine, and Meadow Streets; proposed 3way roundabout at Sunderland Road and Montague Road
- Alternative 2: proposed signal at North Pleasant, Pine, and Meadow Streets; proposed 4way roundabout at Sunderland Road and Montague Road



- Alternative 3: proposed signal at North Pleasant, Pine, and Meadow Streets; T-intersection for Sunderland Road at Montague Road
- Alternative 4: proposed signal at North Pleasant, Pine, and Meadow Streets; T-intersection for Montague Road at Sunderland Road
- Alternative 5: proposed roundabout at North Pleasant, Pine, and Meadow Streets; proposed
 3-way roundabout at Sunderland Road and Montague Road
- Alternative 6: proposed roundabout at North Pleasant, Pine, and Meadow Streets; proposed
 4-way roundabout at Sunderland Road and Montague Road
- Alternative 7: proposed roundabout at North Pleasant, Pine, and Meadow Streets; Tintersection for Sunderland Road at Montague Road
- Alternative 8: proposed roundabout at North Pleasant, Pine, and Meadow Streets; Tintersection for Montague Road at Sunderland Road



Section 3

Existing Conditions

3.1 North Pleasant Street at Pine Street and Meadow Street

North Pleasant Street is an urban minor arterial that connects downtown Amherst and the University of Massachusetts campus to the south with State Route 116 and the towns of Sunderland and Montague to the north. Meadow Street is an urban principal arterial that connects to Route 116 to the west. Meadow Street is designated as Route 63 between the study intersections and Route 116. Pine Street is an urban minor arterial that serves residential areas to the east toward the town of Leverett.

The intersection North Pleasant Street at Pine Street and Meadow Street, located in the center of North Amherst, is currently controlled by a traffic signal. Both left and right turn lanes are provided on both approaches of North Pleasant Street, while Meadow Street and Pine Street are single lane approaches. Crosswalks are provided across the west, north, and east sides of the intersection. The intersection is depicted on Figure 3-1.

3.2 Sunderland Road at Montague Road

Less than 200 ft north of the Pine Street and Meadow Street intersection, North Pleasant Street intersects Sunderland Road and Montague Road.

Sunderland Road extends north of the study area, ending at Route 116 just before the Sunderland town line. It is an urban minor arterial that serves as an important route for traffic heading to the University of Massachusetts Amherst. Montague Road is an urban principal arterial that carries Route 63 north toward Montague and Millers Falls. It becomes a state highway immediately north of Sunderland Road.

The intersection is presently stop sign controlled on the Montague Road approach, allowing free flow for southbound Sunderland Road and northbound North Pleasant Street. There are no crosswalks at the intersection itself, but approximately 100 ft north of the intersection there are crosswalks across both roads, in front of the North Amherst Library, which occupies the space between the two roads at the intersection. The intersection is depicted on Figure 3-1.

3.3 Shopping Plaza Driveways

Located on the east side of Montague Road north of the split from Sunderland Road is a shopping plaza with two driveways. The southern of these is marked as entry-only, while the northern is two-way. These driveways also serve an apartment complex behind the shopping plaza.



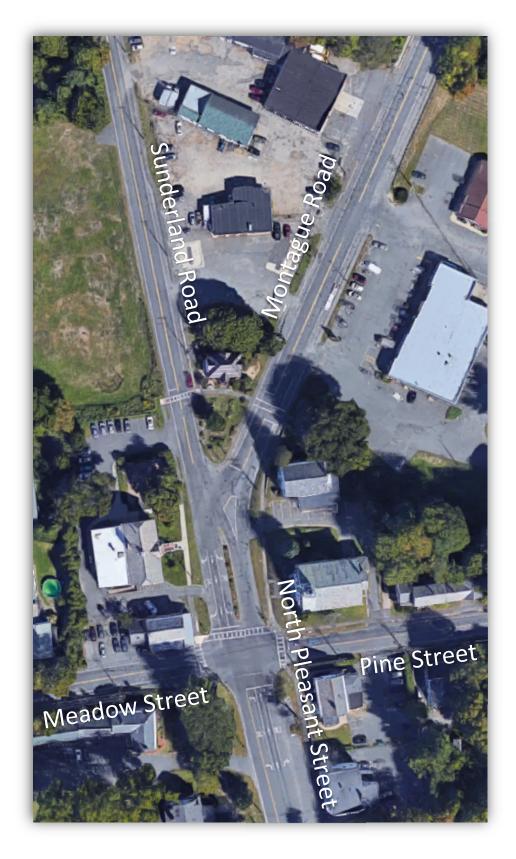


Figure 3-1 - Site Overview (courtesy of Google Maps. Downloaded January 2019)



3.4 Existing Traffic Volumes

Turning Movement Count (TMC) and Automatic Traffic Recorder (ATR) data was collected by Innovative Data, LLC in October 2017 at the study intersections. TMC data collected include Weekday Morning (AM) and Afternoon (PM) peak periods along with the Saturday Midday peak period. This data supplements traffic count data previously collected by Innovative Data, LLC from April and May 2013 and data collected by UMass Amherst in December 2010.

As the most recent Turning Movement Counts (TMCs) were collected in 2017, determination of a growth rate was necessary to project the data to base year 2018 and then the 20-year design horizon as part of the Future Conditions analysis. To determine this growth rate, the 2017 data was compared to 2013 data and 2010 data obtained from previous studies. As shown in Table 3-1, traffic growth during the AM peak period was higher from 2013 to 2017 while traffic growth during the PM peak period was higher during the 2010 to 2013 timeframe. Despite this inconsistency, the overall annual traffic growth from 2010 to 2017 was less than 1% under both AM and PM peak periods. As such, 1% was selected as a moderately conservative annual growth rate to represent all peak periods.

Table 3-1 TMC Growth Rate Calculations

Period	2010	2013	2010-2013 Growth	2017 2013-2017 Growt		2010-2017 Growth
AM TMC	1224	1216	-0.22%	1278	1.25%	0.62%
PM TMC	1549	1619	1.48%	1590	-0.45%	0.37%

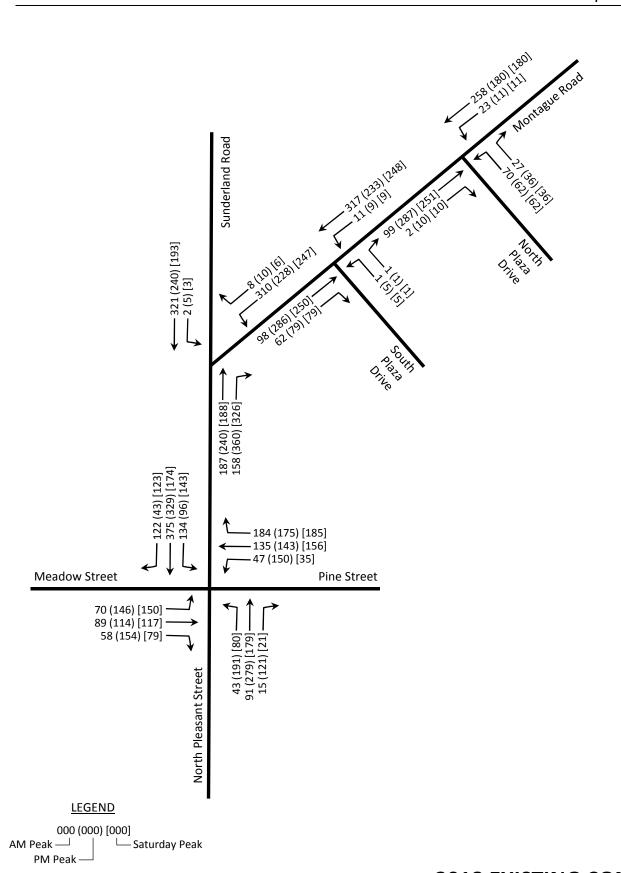
2018 existing conditions traffic volumes were obtained by applying the 1% background growth rate to the 2017 (for AM and PM peak) and 2013 (for Saturday peak) TMC volumes. These volumes were then manually balanced to eliminate any discrepancies between the two intersections.

The traffic count data included AM and PM peak turning movement counts for the southern driveway to the shopping plaza but omitted the Saturday Midday peak. The busier PM peak entering and exiting traffic volumes at the site driveway were used to supplement the Saturday data. Figure 3-2 depicts the 2018 Existing Condition traffic volumes.

It should be noted that the 2017 TMC data, and therefore the 2018 Existing Condition traffic volumes, shows a different composition of turning movement demand during the Weekday PM peak hour at the intersection of North Pleasant Street at Meadow Street and Pine Street than the 2013 TMC data used in the 2015 report prepared by CDM Smith. The data showed a 3% increase in vehicles traveling through the intersection between the 2013 and the 2018 Existing Conditions traffic volumes, but a 41% increase in turning vehicles at the intersection. Turning movements which notably increased in demand from 2013 to 2018 include the North Pleasant Street left turn and right turn movements, the Meadow Street right turn movement, and the Pine Street right turn movement. The Weekday AM peak hour traffic data showed a consistent turning movement demand composition between 2013 TMC data and the 2018 Existing Conditions traffic volumes.



Not to Scale







3.5 Analysis Performance Measures

Critical performance measures evaluated for study area intersections using Sidra Intersection 7.0 Plus include:

- Level of Service (Definition Below)
- Volume to Capacity Ratio (v/c) A ratio comparing roadway demand to roadway capacity.
- Delay Average delay per vehicle measured in seconds.
- 50th Percentile Queue Length (in ft) Maximum length of the queue during a typical cycle
- 95th Percentile Queue Length (in ft) Maximum length of the queue during 95th percentile traffic volumes

Level of Service (LOS) analysis provides a measurement of the delay experienced at an intersection as a result of traffic operations at that intersection. In general, there are six levels of service; Level of Service A to Level of Service F.

The best, Level of Service A, describes a condition of free flow, with low volumes and high speeds. Level of Service B represents a stable traffic flow with operating speeds beginning to be restricted somewhat by traffic conditions. Level of Service C, which is normally utilized for design purposes, describes a stable condition of traffic operation. Level of Service D reflects a condition of more restrictive movements for motorists and influence of congestion becomes more noticeable. Level of Service E is representative of the actual capacity of the roadway or intersection and involves delay to all motorists due to congestion. The worst, Level of Service F, is described as force flow where complete congestion occurs, and in extreme cases, the volume passing a given point drops to zero. This is considered an unacceptable traffic operating condition.

Level of Service is defined differently based on vehicle delay at roundabouts, signalized intersections, and unsignalized intersections. The vehicle delay criteria that determine Level of Service at signalized and unsignalized intersections are defined in Table 3-2.

Table 3-2 LOS Criteria

Level Of Service			Control Delay Per Vehicle (Seconds)
	Roundabouts	Signalized Intersection	Unsignalized Intersection
Α	≤10	≤10	≤10
В	>10 and ≤20	>10 and ≤20	>10 and ≤15
С	>20 and ≤35	>20 and ≤35	>15 and ≤25
D	>35 and ≤50	≤50 >35 and ≤55 >2	
E	>50 and ≤70	>55 and ≤80	>35 and ≤50
F	>70	>80	>50

Source: 2010 Highway Capacity Manual, Transportation Research Board



3.6 Existing Conditions Capacity Analysis

Based on the developed Sidra site models, Table 3-3 details the estimated existing traffic operations at the two intersections in the study area.

Table 3-3 Existing Intersection Capacity Analysis

2018 Existing Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	C (22.0)	0.21	C (27.9)	0.69	B (17.3)	0.28
	NB	B (13.3)	0.17	B (16.2)	0.58	B (14.3)	0.33
	NBR	A (0.6)	0.02	A (0.9)	0.12	A (0.7)	0.03
	SBL	B (15.7)	0.33	C (20.4)	0.39	B (18.4)	0.42
North Pleasant Street / Meadow Street / Pine Street	SB	C (21.0)	0.74	B (16.6)	0.59	B (14.0)	0.29
Weddow Street / Time Street	SBR	A (0.8)	0.14	A (1.0)	0.05	A (1.0	0.16
	EB	B (12.7)	0.49	C (33.8)	0.89	C (26.8)	0.81
	WB	B (11.1)	0.56	C (31.2)	0.88	B (12.4)	0.66
	OVERALL	B (13.7)	0.74	C (23.8)	0.89	B (15.5)	0.81
	NB	A (0.0)	0.12	A (0.0)	0.15	A (0.0)	0.15
	NBR	A (4.4)	0.16	A (6.3)	0.34	A (6.3)	0.34
	SB	A (1.6)	0.21	A (1.3)	0.16	A (1.0)	0.12
Montague Road / Sunderland Road	SBL	A (4.2)	0.21	A (3.9)	0.16	A (3.7)	0.12
Noau	WBL	F (50.2)	0.87	E (37.0)	0.73	E (44.9)	0.82
	WBR	E (45.4)	0.87	D (31.6)	0.73	E (40.4)	0.82
C CDMC ''I	OVERALL	B (16.8)	0.87	B (10.4)	0.73	B (14.1)	0.82

Source: CDM Smith

As depicted in Table 3-3, at the intersection of North Pleasant Street at Meadow Street and Pine Street, all approach movements operate at acceptable levels of service under all study peak hours according to the Sidra analysis. At the intersection of Montague Road and Sunderland Road, vehicles traveling along the stop-controlled Montague Road approach to the intersection experience longer delays under all peak hours. The left turn Montague Road movement operates at unacceptable LOS E or F under all peak hours. The right turn Montague Road movement operates at unacceptable LOS E under the Weekday AM and Saturday Midday peak hours.

The traffic operations based on the 2018 Existing Conditions traffic volumes are generally consistent with those presented in the previous studies. The North Pleasant Street at Meadow Street and Pine Street intersection approaches with substantially increased turning movement demand under 2018 traffic volumes show increased delay during the PM peak analysis compared to the 2013 traffic volumes.

3.7 Existing Conditions Queue Analysis

In addition to the capacity analysis, CDM Smith conducted a queue analysis to evaluate vehicle storage deficiencies at the existing intersections. Table 3-4 details the available storage and



estimated vehicle queues. Available storage is assumed to be either the directly measured auxiliary lane length or the distance to the next significant intersection along a through lane. Vehicle queues exceeding the available storage are identified in **bold type**.

Table 3-4 Existing Intersection Queue Analysis

2018 Existing	2018 Existing Conditions			Weekday P.M. Peak	Saturday Peak	
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)			
	NBL	165	21/34	108/ 177	41/67	
	NB	750	40/66	136/223	85/138	
	NBR	100	2/3	13/21	2/4	
North Pleasant Street /	SBL	90	61/ 99	51/83	69/ 113	
Meadow Street / Pine Street	SB	110	202/329	149/244	74/ 121	
	SBR	90	14/23	5/9	17/28	
	EB	1,800	107/175	278/454	206/336	
	WB	540	143/234	311/507	193/316	
	NB	110	0/0	0/0	0/0	
Montague Road / Sunderland	NBR	140	9/23	25/62	25/62	
Road	SB	2,000	1/2	1/2	0/1	
COMO III	WB	1,550	128/319	71/176	106/265	

Source: CDM Smith

The analysis of the existing intersections estimates queues in excess of the storage capacities at multiple approaches at North Pleasant Street / Meadow Street / Pine Street in all three peak periods. The northbound left turn queue lengths during the PM peak extends slightly longer than the fully developed storage bay. However, the additional vehicle storage necessary to accommodate the 95th percentile queue may in practice be available through the taper area, thereby avoiding disruption of the flow of traffic in the adjacent northbound travel lane. The queue lengths along the southbound approach, however, are estimated to spill into the intersection of Montague Road and Sunderland Road, presenting an obstruction for drivers attempting to enter the roadway from Montague Road.



Section 4

Future Conditions without Improvements

4.1 Growth Rate

As described in Section 3.4 Existing Traffic Volumes, the Turning Movement Counts (TMCs) were collected in 2017 and an annual growth rate was necessary to project the data to 2018 and then to the 20-year design horizon. An annual growth rate of 1% was selected as a moderately conservative annual growth rate to represent all peak periods.

4.2 Background Developments

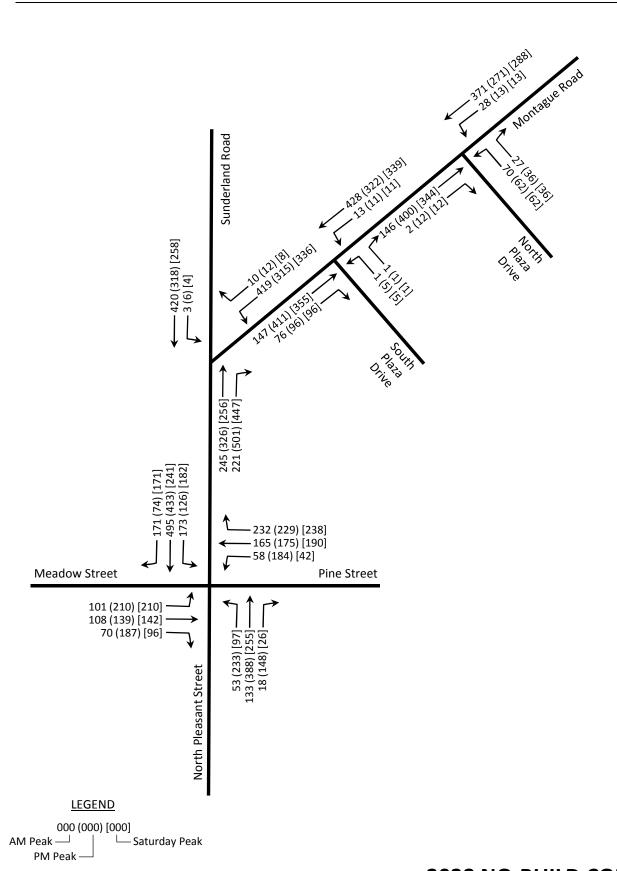
CDM Smith contacted the Town of Amherst to evaluate other developments which may impact traffic at the study intersections. Two developments were identified for evaluation by the Town:

- North Square at the Mill District (located on Cowls Road between Sunderland Road and Montague Road)
- Registered Marijuana Dispensary (RMD) at 169 Meadow Street

The North Square development is a mixed-use development consisting of 130 dwelling units (20% affordable dwelling units) with 22,000 square feet of commercial/retail/office space. The RMD at 169 Meadow Street will replace an existing Auction House. Traffic impact studies for these two developments were provided by the town and are included in the appendix. The study for North Square at the Mill District showed a modest increase in traffic volumes through the study area. The 169 Meadow Street study forecast a decrease in traffic volumes, based on the change in use from the present "specialty retail" (auction house) to "medical office" resulting in 53 fewer trip ends per day. The traffic associated with the North Square development were added to the study area intersections along with the projection of the annual growth rate in order to develop the 2038 Future No Build Conditions traffic network, depicted in Figure 4-1.



Not to Scale





2038 NO-BUILD CONDITIONS PEAK HOUR TRAFFIC VOLUMES

4.3 Future No-Build Condition Capacity Analysis

CDM Smith analyzed the study intersections under 2038 No Build Condition traffic volumes to evaluate the impact of expected ambient growth and other developments. Under these conditions, Table 4-1 details the forecasted traffic operations at the two existing intersections in 2038.

Table 4-1 Future No-Build Intersection Capacity Analysis

2038 No-Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.7)	0.55	F (130.8)	1.15	B (19.7)	0.40
	NB	B (13.7)	0.25	D (45.4)	0.95	B (15.7)	0.53
	NBR	A (0.8)	0.02	A (0.8)	0.14	A (0.7)	0.03
	SBL	B (18.2)	0.47	C (34.4)	0.71	C (25.3)	0.65
North Pleasant Street / Meadow Street / Pine Street	SB	F (78.5)	1.07	C (30.0)	0.87	B (14.8)	0.40
medden da dat y t me da dat	SBR	A (1.2)	0.20	A (1.4)	0.09	A (1.5)	0.23
	EB	C (23.8)	0.75	F (247.5)	1.50	F (217.3)	1.42
	WB	B (16.1)	0.71	F (44.7)	1.01	B (18.9)	0.81
	OVERALL	C (32.5)	1.07	F (86.9)	1.50	E (59.2)	1.42
	NB	A (0.0)	0.15	A (1.9)	0.20	A (1.9)	0.20
	NBR	A (5.1)	0.22	A (8.1)	0.47	A (8.0)	0.46
	SB	A (2.2)	0.27	A (1.7)	0.21	A (1.3)	0.17
Montague Road / Sunderland Road	SBL	A (4.9)	0.27	A (4.6)	0.21	A (4.2)	0.17
Noud	WBL	F (315.7)	1.60	F (262.7)	1.45	F (315.6)	1.59
	WBR	F (308.0)	1.60	F (253.2)	1.45	F (307.7)	1.59
a com a wi	OVERALL	F (100.0)	1.60	E (61.4)	1.45	F (87.1)	1.59

Source: CDM Smith

As depicted in Table 4-1, under Future Conditions without improvements, several movements at the intersection of North Pleasant Street at Meadow Street and Pine Street are predicted to operate at unacceptable levels of service under the study peak hours. The following movements are anticipated to operate at unacceptable LOS F under the respective study peak hours:

- AM Peak
 - Southbound through movement
- PM Peak
 - Northbound left turn movement
 - Eastbound shared lane movement
 - Westbound shared lane movement



- Saturday Midday
 - Eastbound shared lane movement

At the intersection of Montague Road and Sunderland Road, vehicles traveling along the stop-controlled Montague Road approach to the intersection are forecasted to experience even longer delays under all peak hours. The left and right turn Montague Road movements are all anticipated to operate at unacceptable LOS F under all peak hours.

4.4 Future No-Build Condition Queue Analysis

In addition to the capacity analysis, CDM Smith conducted a queue analysis to evaluate vehicle storage deficiencies at the existing intersections. Table 4-2 details the available storage and estimated vehicle queues. Available storage is assumed to be either the directly measured auxiliary lane length or the distance to the next significant intersection along a through lane. Vehicle queues exceeding the available storage are identified in **bold type**.

Table 4-2 Future No-Build Intersection Queue Analysis

2038 No-Buil	2038 No-Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NBL	165	33/54	270/441	54/89		
	NB	750	61/100	288/469	134/218		
	NBR	100	2/4	15/24	3/5		
North Pleasant Street /	SBL	90	87/ 143	84/137	105/171		
Meadow Street / Pine Street	SB	110	498/813	255/416	109/ 178		
	SBR	90	25/40	11/18	30/49		
	EB	1,800	189/308	828/1,352	700/1,142		
	WB	540	220/360	416/ 679	303/494		
	NB	110	0/0	15/37	15/37		
Montague Road / Sunderland Road	NBR	140	14/35	43/108	42/105		
	SB	2,000	1/3	1/3	1/1		
20042	WB	1,550	672/ 1,670	471/1,172	631/ 1,567		

Source: CDM Smith

Under 2038 No Build Conditions, at the intersection of North Pleasant Street at Meadow Street and Pine Street, the available storage of the northbound left turn lane is forecasted to be exceeded by both 50 and 95th percentile vehicle queues during the Weekday PM peak. The 95th percentile vehicle queue length is expected to exceed the southbound left turn and through lane storage during all peak hours. Similarly, the 50th percentile vehicle queue length is expected to exceed the southbound left turn lane storage during the Saturday Midday peak hour while exceeding the through lane storage during the Weekday AM and PM peak hours. The westbound queue length under Weekday PM peak hour is forecasted to extend beyond Harris Street, impeding vehicle access to residences.



Section 5

Future Conditions with Improvements

5.1 Description of Build Scenarios

As mentioned in Section 1, this study evaluates multiple permutations of potential traffic control options at each intersection including the installation of a roundabout at one or both intersections. Alternatives 1 through 4 assume the existing traffic signal at North Pleasant Street, Meadow Street, and Pine Street will be upgraded, while alternatives 5 through 8 assume this signal is replaced with a roundabout. The Build Condition Alternatives are defined as follows:

5.1.1 Alternative 1

Alternative 1 realigns Sunderland Road to end at a 3-way roundabout at Montague Road, north of the North Amherst Library. The shopping plaza entrances on the east side of Montague Road would both become right-in/right-out, with left turns utilizing the roundabout. This alternative retains the signal at North Pleasant Street, Meadow Street, and Pine Street, with improvements including a left turn lane on Meadow Street, and a crosswalk across the south approach. The general concept of this roundabout control is depicted in Appendix F.

5.1.2 Alternative 2

Alternative 2 realigns Sunderland Road to end at a 4-way roundabout at Montague Road, north of the North Amherst Library, aligned with the north shopping plaza driveway. The south driveway would be retained as an entrance from both directions. This alternative retains the signal at North Pleasant Street, Meadow Street, and Pine Street, with improvements including a left turn lane on Meadow Street, and a crosswalk across the south approach. The general concept of this roundabout control is depicted in Appendix F.

5.1.3 Alternative 3

Alternative 3 realigns Sunderland Road to end at a 4-way intersection at Montague Road, north of the North Amherst Library, aligned with the south shopping plaza driveway. The north driveway would be retained in its existing configuration. Stop control is assumed for Sunderland Road. This alternative retains the signal at North Pleasant Street, Meadow Street, and Pine Street, with improvements including a left turn lane on Meadow Street, and a crosswalk across the south approach. The general concept of this roundabout control is depicted in Appendix F.

5.1.4 Alternative 4

Alternative 4 realigns Montague Road to end at a 3-way intersection with Sunderland Road, north of the North Amherst Library. Stop control is assumed for Montague Road. This alternative retains the signal at North Pleasant Street, Meadow Street, and Pine Street, with improvements including a left turn lane on Meadow Street, and a crosswalk across the south approach.



5.1.5 Alternative 5

Alternative 5 realigns Sunderland Road to end at a 3-way roundabout at Montague Road, north of the North Amherst Library. The shopping plaza entrances on the east side of Montague Road would need to be restricted to right-in/right-out operation (those wishing to turn left would use the roundabout to reverse direction). This alternative also replaces the signal at North Pleasant Street, Meadow Street, and Pine Street with a roundabout.

5.1.6 Alternative 6

Alternative 6 realigns Sunderland Road to end at a 4-way roundabout at Montague Road, north of the North Amherst Library, aligned with the north shopping plaza driveway. The south driveway would be retained as an entrance-only from both directions. This alternative also replaces the signal at North Pleasant Street, Meadow Street, and Pine Street with a roundabout.

5.1.7 Alternative 7

Alternative 3 realigns Sunderland Road to end at a 4-way intersection at Montague Road, north of the North Amherst Library, aligned with the south shopping plaza driveway. The north driveway would be retained in its existing configuration. Stop control is assumed for Sunderland Road. This alternative also replaces the signal at North Pleasant Street, Meadow Street, and Pine Street with a roundabout.

5.1.8 Alternative 8

Alternative 4 realigns Montague Road to end at a 3-way intersection with Sunderland Road, north of the North Amherst Library. Stop control is assumed for Montague Road. This alternative also replaces the signal at North Pleasant Street, Meadow Street, and Pine Street with a roundabout.

5.2 Build Condition Traffic Volume Networks

In order to develop Build Condition traffic volume networks for each construction alternative, CDM Smith performed minor redistribution of traffic volumes at the intersection of Sunderland Road at Montague Road to reflect the origin and destination of observed vehicle trips relative to the type and orientation of the intersection configuration along with the interaction with the adjacent private driveways. All Build Condition traffic volume networks are depicted in Appendix D.

5.3 Preliminary Roundabout Analysis

CDM Smith conducted a preliminary roundabout analysis at both study intersections to determine a framework for likely circulating, entry, and exit lane configurations. The intent of the preliminary analysis for roundabouts is a "broad brush" approach to identify the number of approach lanes and circulating lanes that may be required based on volumes. For this effort, CDM Smith used the latest version of the Georgia Department of Transportation (GDOT) Roundabout Analysis Tool, Version 4.1¹. This Tool is accepted by the Massachusetts Department of Transportation for analysis of roundabouts. Analysis with the GDOT Tool was conducted using 2038 Build Condition traffic volumes during the Weekday AM, PM and Saturday Midday peak



¹ http://www.dot.ga.gov/DS/SafetyOperation/Roundabouts.

Table 5-1 Montague/Sunderland 3-way Roundabout GDOT Analysis

2038 Build Conditions	Movement	LOS (Delay)	V/C Ratio	Available Storage (ft)	95 th % Queue Length
Weekday A.M. Peak	SWB	A (9)	0.46	1,200	61
	SEB	B (14)	0.60	1,800	104
	NEB	A (7)	0.39	400	49
	SWB	A (8)	0.35	1,200	39
Weekday P.M. Peak	SEB	A (8)	0.41	1,800	50
	NEB	B (11)	0.67	400	138
Saturday Peak	SWB	A (7)	0.33	1,200	36
	SEB	A (7)	0.30	1,800	31
	NEB	A (9)	0.55	400	90

Source: CDM Smith

As depicted in Table 5-1, the three-legged roundabout configuration of Montague Road and Sunderland Road is expected to operate at acceptable levels of service during all peak hours according to the GDOT analysis assuming single lane approach entries and exits along with a single circulating lane.

Table 5-2 Montague/Sunderland 4-way Roundabout GDOT Analysis

2038 Build Conditions	Movement	LOS (Delay)	V/C Ratio	Available Storage (ft)	95 th % Queue Length
Weekday A.M. Peak	SWB	A (10)	0.46	1,200	63
	SEB	B (14)	0.60	1,800	103
	NEB	A (7)	0.38	400	49
	NWB	A (6)	0.15	20	13
	SWB	A (8)	0.37	1,200	43
Weekday P.M. Peak	SEB	A (9)	0.41	1,800	52
Weekuay P.IVI. Feak	NEB	B (10)	0.63	400	119
	NWB	A (8)	0.20	20	16
	SWB	A (8)	0.36	1,200	41
Saturday Peak	SEB	A (8)	0.34	1,800	38
Saturday reak	NEB	A (8)	0.52	400	79
	NWB	A (7)	0.17	20	14

Source: CDM Smith

As depicted in Table 5-2, the four-legged roundabout configuration of Montague Road and Sunderland Road is expected to operate at acceptable levels of service during all peak hours according to the GDOT analysis assuming single lane approach entries and exits along with a single circulating lane.



Table 5-3 North Pleasant St/Meadow St/Pine St 4-way Roundabout GDOT Analysis

2038 Build Conditions	Movement	LOS (Delay)	V/C Ratio	Available Storage (ft)	95 th % Queue Length
	SB	A (7.8)	0.42	400	53
Weekday A.M. Peak	WB	A (5.5)	0.23	540	22
Weekuay A.M. Peak	NB	A (4.9)	0.11	750	9
	EB	A (10.0)	0.40	1,800	48
	SB	B (11.0)	0.49	400	69
Weekday D.M. Dook	WB	C (19.0)	0.70	540	139
Weekday P.M. Peak	NB	B (11.3)	0.55	750	86
	EB	D (34.1)	0.87	1,800	263
	SB	A (6.6)	0.31	400	34
Saturday Peak	WB	A (7.8)	0.31	540	33
	NB	A (6.8)	0.24	750	23
	EB	B (10.2)	0.50	1,800	72

Source: CDM Smith

Table 5-3 depicts the preliminary GDOT capacity and queue analysis for roundabout control at the North Pleasant Street at Meadows Street and Pine Street intersection. According to the GDOT Tool, the vehicle demand during the Weekday PM peak hour at the intersection of North Pleasant Street at Meadow Street and Pine Street necessitates a hybrid multi-lane entry roundabout. Acceptable Level of Service is forecasted by providing two-lane entry for all approaches except the eastbound Meadow Street approach to the intersection. The westbound Pine Street approach would require a standard entry lane as well as a right turn bypass lane. Two circulating lanes would receive the northbound and southbound multi-lane approaches.

All preliminary roundabout analysis output for 2038 Build Conditions are found in Appendix G.

5.4 Build Condition Alternative Analysis

In November 2010, CDM Smith completed the design of twin roundabouts at the intersections of West Street at Bay Road and West Street at West Bay Road in Amherst. Following the construction of the twin roundabouts, the University of Massachusetts gathered field measurements of vehicle behavior, including gap acceptance. The gap acceptance field data measured by the University of Massachusetts at the roundabouts were used to calculate Amherst specific critical gap values.

Critical gap is broadly defined as the smallest gap between vehicles that a driver is willing to accept to merge with the circulating traffic. This value is a vital element in the analysis of roundabout operations as vehicles yield upon entry to vehicles already circulating within the roundabout. Higher critical gap values would correspond to vehicles accepting fewer gaps to enter in the circulating flow of the roundabout, thereby increasing entry delay. Lower critical gap values would correspond to vehicles accepting a greater number of gaps to enter the circulating flow of the roundabout, thereby decreasing entry delay.



The computation of critical gap values at the twin Amherst roundabouts yielded a critical gap of 2.5 seconds at the West Bay Road and West Street roundabout and 4.5 seconds at the Bay Road and West Street roundabout.

For the purposes of providing an analysis representative of local driving behavior, CDM Smith used the more conservative critical gap value of 4.5 seconds in the Build Conditions roundabout models at both study intersections.

Based on the GDOT Tool preliminary roundabout analysis, CDM Smith created Build Condition Sidra roundabout models for the intersection of North Pleasant Street at Meadow Street and Pine Street consisting of the following configuration:

- One-lane entry for eastbound Meadow Street.
- Two-lane entry for all other approaches.
- Standard entry lane along with a right turn bypass lane for the westbound Pine Street approach.
- Two circulating lanes receiving the northbound and southbound multi-lane approaches.

However, based on the results of the Sidra analysis, the forecasted available capacity at the intersection indicated that a smaller roundabout configuration would suffice. CDM Smith iteratively modified the model to determine the roundabout configuration which would require the fewest operating entry, circulating and exit lanes. The Sidra analysis indicated a single lane roundabout with single lane entry and exit would function at acceptable levels, but only if a bypass lane is included on the Pine Street westbound approach.

The following Build Condition analysis tables detail the estimated traffic operations at the two study intersections under both 2018 and 2038 traffic volume conditions. The roundabout analyses presented for the intersection of North Pleasant Street at Meadow Street and Pine Street under Alternatives 5-8 reflect the refined single circulating lane configuration.

5.4.1 Alternative 1

The analysis of Alternative 1 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
 - Install eastbound Meadow Street left turn lane
 - Signal phasing, timing and setting modifications
 - Advanced eastbound phase with southbound right turn overlap movement
 - o Protected northbound and southbound left turn phase
- Sunderland Road at Montague Road



- Realigned Sunderland Road to intersect Montague Road at a 3-legged roundabout
- Roundabout excludes adjacent plaza driveway from roundabout control

Tables 5-4 and 5-5 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-6 and 5-7 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.

Table 5-4 Alternative 1 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekda Pea		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.5)	0.26	F (165.4)	1.21	D (38.9)	0.55
	NB	C (25.6)	0.30	F (92.2)	1.05	C (31.5)	0.67
	NBR	A (1.3)	0.02	A (1.1)	0.13	A (1.3)	0.03
	SBL	F (101.6)	0.99	D (45.1)	0.67	F (100.0)	0.98
North Pleasant Street /	SB	F (176.0)	1.29	E (66.9)	0.97	C (30.8)	0.66
Meadow Street / Pine Street	SBR	A (2.2)	0.17	A (2.7)	0.08	A (2.0)	0.19
	EBL	B (13.7)	0.27	C (20.3)	0.62	B (19.4)	0.61
	EB	A (9.4)	0.25	A (8.4)	0.35	A (7.0)	0.26
	WB	B (19.3)	0.67	D (48.2)	0.95	C (25.1)	0.79
	OVERALL	E (65.3)	1.29	E (57.0)	1.21	C (28.8)	0.98
	SWB	A (7.4)	0.37	A (6.4)	0.26	A (6.0)	0.25
Montague Road / Sunderland Road (roundabout)	SEB	A (9.9)	0.45	A (6.8)	0.31	A (5.8)	0.23
	NEB	A (5.7)	0.32	A (8.6)	0.54	A (7.3)	0.46
C CDM Citl	OVERALL	A (7.6)	0.45	A (7.8)	0.54	A (6.7)	0.46

Source: CDM Smith



Table 5-5 Alternative 1 2018 Intersection Queue Analysis

2018 E	Weekday A.M. Peak	Weekday P.M. Peak	Saturday Peak				
Intersection	n Movement Available Storage (ft)		50 th /95 th Percentile Queue Length (ft				
	NBL	100	30 / 49	277 / 452	69 / 113		
	NB	750	77 / 126	393 / 642	172 / 281		
	NBR	100	3/5	17 / 28	4/6		
North Pleasant Street /	SBL	100	163 / 266	89 / 145	166 / 271		
Meadow Street / Pine	SB	400	672 / 1,097	338 / 551	146 / 239		
Street	SBR	100	31 / 51	14 / 23	33 / 54		
	EBL	100	39 / 64	90 / 148	83 / 136		
	EB	1,800	61 / 100	87 / 143	65 / 106		
	WB	540	230 / 376	455 / 743	320 / 521		
Montague Road /	SWB	1,200	20 / 50	13 / 32	13 / 31		
Sunderland Road	SEB	1,800	29 / 73	16 / 40	11 / 27		
(roundabout)	NEB	400	19 / 48	48 / 119	34 / 84		

Source: CDM Smith

Table 5-6 Alternative 1 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekda Pea		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.9)	0.32	F (266.0)	1.47	D (45.1)	0.67
	NB	C (26.2)	0.37	F (177.8)	1.30	D (45.0)	0.85
	NBR	A (1.7)	0.03	A (1.5)	0.17	A (1.7)	0.04
	SBL	F (164.5)	1.20	E (61.6)	0.82	F (163.6)	1.20
North Pleasant Street /	SB	F (294.9)	1.57	F (135.8)	1.19	E (70.2)	0.97
Meadow Street / Pine Street	SBR	A (3.1)	0.22	A (3.0)	0.10	A (3.2)	0.24
	EBL	B (15.5)	0.40	D (35.9)	0.82	F (86.1)	1.03
	EB	B (10.2)	0.30	B (10.3)	0.42	A (8.6)	0.32
	WB	C (27.3)	0.82	F (106.6)	1.18	D (49.4)	0.97
	OVERALL	F (104.5)	1.57	F (106.9)	1.47	D (54.7)	1.20
	SWB	A (9.5)	0.48	A (8.0)	0.35	A (7.3)	0.33
Montague Road / Sunderland Road	SEB	B (14.6)	0.61	A (8.4)	0.40	A (7.0)	0.30
(roundabout)	NEB	A (6.7)	0.40	B (11.4)	0.67	A (9.0)	0.56
, , ,	OVERALL	B (10.2)	0.61	B (10.0)	0.67	A (8.2)	0.56

Source: CDM Smith



Table 5-7 Alternative 1 2038 Intersection Queue Analysis

2038 Build Conditions			Weekday A.M. Peak	Weekday P.M. Peak	Saturday Peak	
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)			
	NBL	100	38/61	439/717	90/ 147	
	NB	750	97/158	672 /1,096	245/400	
	NBR	100	4/7	25/40	5/9	
	SBL	100	271/441	121/198	276/451	
North Pleasant Street / Meadow Street / Pine Street	SB	400	1,046/1,708	601/981	243/397	
Weddow Street / Time Street	SBR	100	46/74	18/30	51/83	
	EBL	100	50/81	130/212	176/287	
	EB	1,800	82/134	123/201	88/144	
	WB	540	340/ 555	684/1,117	532/ 869	
Montague Road / Sunderland	SWB	1,200	32/80	17/43	17/42	
Road	SEB	1,800	58/143	22/55	15/37	
(roundabout)	NEB	400	26/65	77/191	50/124	

Source: CDM Smith

As shown in Tables 5-4 and 5-6, the traffic signal option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to underserve both the existing and future vehicle demand at the intersection. Approaches forecast to have notably deficient capacity under existing and future traffic conditions are consistent with the No-Build analysis findings and include the southbound North Pleasant Street approach during all study peak hours and the northbound North Pleasant Street approach during the PM peak hour. The westbound Pine Street approach is forecast to operate at a failing LOS F under the 2038 Build Conditions PM peak hour.

The Build Condition installation of the Meadow Street eastbound left turn lane and protected phase, however, is projected to greatly reduce the delay for the eastbound approach from under the 2038 PM and Saturday Midday peak hours. By removing the left turning vehicles which from the eastbound flow, through and right turning eastbound vehicles process through the intersection more efficiently. The increases in delay values at other approaches is due to proposed protected phasing for left turn lanes which reduce vehicle conflicts but detract from available green phase time percentage allocated to all other phases.

This analysis result of the traffic control signal operation contrasts the expected performance of an upgraded traffic control signal as defined in the 2015 evaluation conducted by CDM Smith. As mentioned under Section 3.4 Existing Traffic Volumes, the composition of turning movement demand versus through travel demand at the intersection of North Pleasant Street at Pine Street and Meadow Street changed considerably from 2013 to 2017 during the PM peak period. Despite proposed phasing improvements to better control turning movement demand at this intersection, the relatively balanced demand at each approach is too high for each approach to be served efficiently.



As shown in Tables 5-5 and 5-7, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under traffic signal control exceed available storage at many approach movements under existing and future vehicle demand. Approaches forecast to have notably excessive vehicle queue lengths under existing and future traffic conditions includes the southbound North Pleasant Street approach during all study peak hours and the northbound North Pleasant Street approach during the PM peak hour. The westbound queue length under Weekday PM peak hour is forecasted to extend beyond Harris Street, impeding vehicle access to residences. The incorporation of the eastbound left turn lane and protected phasing reduce the No-Build projected queue lengths from distances greater than 1,000 feet to no more than 300 feet under the Build Condition.

According to the analysis, the 3-legged roundabout option at the intersection of Sunderland Road at Montague Road operates efficiently under both 2018 and 2038 traffic volume demand. All vehicle queues are anticipated to be accommodated within the available storage. However, the forecasted southbound vehicle queues along North Pleasant Street under both 2018 and 2038 traffic volumes may at times extend back into the roundabout, forcing all circulation at the roundabout to stop.

Alternative 1 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed signal control phasing and timing modifications at the North Pleasant Street at Meadow Street and Pine Street intersection along with the eastbound Meadow Street left turn lane and advance phase would improve the control of heavy turning movement demand. The eastbound Meadow Street approach is projected to experience significantly reduced delay and vehicle queuing under Alternative 1.

Issues:

This control of turning vehicles and subsequent reduction in vehicle conflicts would come at the detriment of other approaches, however, as the proposed timing and phasing modifications would reduce the available percentage of the cycle length attributable to each phase.

Vehicle queueing exceeds available capacity for movements along the northbound, southbound, and westbound approaches to the intersection. The southbound vehicle queues may disrupt traffic flow at the adjacent roundabout proposed at Sunderland Road and Montague Road under this alternative.

Sunderland Road at Montague Road:

Benefits:

The 3-legged roundabout configuration at this intersection is forecast to operate efficiently with no vehicle queuing issues.



Issues:

The roundabout operations may be disrupted by the vehicle queuing at the adjacent study intersection.

5.4.2 Alternative 2

The analysis of Alternative 2 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
 - Install eastbound Meadow Street left turn lane
 - Signal phasing, timing and setting modifications
 - Advanced eastbound phase with southbound right turn overlap movement
 - o Protected northbound and southbound left turn phase
- Sunderland Road at Montague Road
 - Realigned Sunderland Road to intersect Montague Road at a 4-legged roundabout
 - Roundabout incorporates adjacent plaza driveway into roundabout control

Tables 5-8 and 5-9 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-10 and 5-11 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.



Table 5-8 Alternative 2 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekda Pea		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.5)	0.26	F (165.4)	1.21	D (38.9)	0.55
	NB	C (25.6)	0.30	F (92.2)	1.05	C (31.5)	0.67
	NBR	A (1.3)	0.02	A (1.1)	0.13	A (1.3)	0.03
	SBL	F (101.6)	0.99	D (45.1)	0.67	F (100.0)	0.98
North Pleasant Street /	SB	F (176.0)	1.29	E (66.9)	0.97	C (30.8)	0.66
Meadow Street / Pine Street	SBR	A (2.2)	0.17	A (2.7)	0.08	A (2.0)	0.19
	EBL	B (13.7)	0.27	C (20.3)	0.62	B (19.4)	0.61
	EB	A (9.4)	0.25	A (8.4)	0.35	A (7.0)	0.26
	WB	B (19.3)	0.67	D (48.2)	0.95	C (25.1)	0.79
	OVERALL	E (65.3)	1.29	E (57.0)	1.21	C (28.8)	0.98
	SWB	A (7.5)	0.37	A (6.7)	0.28	A (6.3)	0.27
Montague Road / Sunderland	SEB	B (10.0)	0.46	B (13.1)	0.64	A (6.3)	0.26
Road	NEB	A (5.1)	0.27	A (8.5)	0.53	A (6.8)	0.43
(roundabout)	NWB	A (4.9)	0.11	A (7.3)	0.16	A (6.1)	0.14
Course CDM Coulth	OVERALL	A (7.4)	0.46	A (9.8)	0.64	A (6.5)	0.43

Source: CDM Smith

Table 5-9 Alternative 2 2018 Intersection Queue Analysis

2018 Build Conditions			Weekday A.M. Peak	Weekday P.M. Peak	Saturday Peak	
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)			
	NBL	100	30 / 49	277 / 452	69 / 113	
	NB	750	77 / 126	393 / 642	172 / 281	
	NBR	100	3/5	17 / 28	4/6	
North Pleasant Street / Meadow Street / Pine Street	SBL	100	163 / 266	89 / 145	166 / 271	
	SB	400	672 / 1,097	338 / 551	146 / 239	
Weddow Street / Time Street	SBR	100	31 / 51	14 / 23	33 / 54	
	EBL	100	39 / 64	90 / 148	83 / 136	
	EB	1,800	61 / 100	87 / 143	65 / 106	
	WB	540	230 / 376	455 / 743	320 / 521	
	SWB	1,200	20 / 50	13 / 33	14 / 34	
Montague Road / Sunderland Road	SEB	1,800	30 / 75	80 / 198	13 / 31	
(roundabout)	NEB	400	15 / 38	46 / 113	31 / 76	
, , , , , , , , , , , , , , , , , , , ,	NWB	20	5 / 12	7 / 17	6 / 14	

Source: CDM Smith



Table 5-10 Alternative 2 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekda Pea	•	Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.9)	0.32	F (266.0)	1.47	D (45.1)	0.67
	NB	C (26.2)	0.37	F (177.8)	1.30	D (45.0)	0.85
	NBR	A (1.7)	0.03	A (1.5)	0.17	A (1.7)	0.04
	SBL	F (164.5)	1.20	E (61.6)	0.82	F (163.6)	1.20
North Pleasant Street /	SB	F (294.9)	1.57	F (135.8)	1.19	E (70.2)	0.97
Meadow Street / Pine Street	SBR	A (3.1)	0.22	A (3.0)	0.10	A (3.2)	0.24
	EBL	B (15.5)	0.40	D (35.9)	0.82	F (86.1)	1.03
	EB	B (10.2)	0.30	B (10.3)	0.42	A (8.6)	0.32
	WB	C (27.3)	0.82	F (106.6)	1.18	D (49.4)	0.97
	OVERALL	F (104.5)	1.57	F (106.9)	1.47	D (54.7)	1.20
	SWB	A (9.7)	0.48	A (8.4)	0.36	A (7.8)	0.36
Montague Road / Sunderland Road	SEB	B (14.9)	0.62	C (24.6)	0.84	A (7.8)	0.34
	NEB	A (5.8)	0.33	B (11.2)	0.66	A (8.2)	0.52
(roundabout)	NWB	A (5.6)	0.15	A (9.4)	0.24	A (7.5)	0.19
	OVERALL	A (9.9)	0.62	C (15.6)	0.84	A (8.0)	0.52

Source: CDM Smith

Table 5-11 Alternative 2 2038 Intersection Queue Analysis

2038 Build Conditions			Weekday A.M. Peak	Weekday P.M. Peak	Saturday Peak	
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)			
	NBL	100	38/61	439/717	90/ 147	
	NB	750	97/158	672 /1,096	245/400	
	NBR	100	4/7	25/40	5/9	
North Pleasant Street / Meadow Street / Pine Street	SBL	100	271/441	121/198	276/451	
	SB	400	1,046/1,708	601/981	243/397	
Weddow Street / Time Street	SBR	100	46/74	18/30	51/83	
	EBL	100	50/81	130/212	176/287	
	EB	1,800	82/134	123/201	88/144	
	WB	540	340/ 555	684/1,117	532/ 869	
	SWB	1,200	33/82	19/46	19/47	
Montague Road / Sunderland Road	SEB	1,800	59/146	196/487	17/43	
(roundabout)	NEB	400	20/50	73/181	44/110	
(i ouridabout)	NWB	20	6/16	10/24	8/19	

Source: CDM Smith

As shown in Tables 5-8 and 5-10, the traffic signal option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to underserve both the existing and future vehicle demand at the intersection. Similar to Alternative 1, approaches forecast to have notably deficient capacity under existing and future traffic conditions are consistent with the No-Build analysis



findings and include the southbound North Pleasant Street approach during all study peak hours and the northbound North Pleasant Street approach during the PM peak hour. The westbound Pine Street approach is forecast to operate at a failing LOS F under the 2038 Build Conditions PM peak hour. The Build Condition installation of the Meadow Street eastbound left turn lane and protected phase, however, is projected to greatly reduce the delay for the eastbound approach from under the 2038 PM and Saturday Midday peak hours. By removing the left turning vehicles which from the eastbound flow, through and right turning eastbound vehicles process through the intersection more efficiently. The increases in delay values at other approaches is due to proposed protected phasing for left turn lanes which reduce vehicle conflicts but detract from available green phase time percentage allocated to all other phases.

As shown in Tables 5-9 and 5-11, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under traffic signal control exceed available storage at many approach movements under existing and future vehicle demand. Approaches forecast to have notably excessive vehicle queue lengths under existing and future traffic conditions include the southbound North Pleasant Street approach during all study peak hours and the northbound North Pleasant Street approach during the PM peak hour. The westbound queue length under Weekday PM peak hour is forecasted to extend beyond Harris Street, impeding vehicle access to residences. The incorporation of the eastbound left turn lane and protected phasing reduce the No-Build projected queue lengths from distances greater than 1,000 feet to no more than 300 feet under the Build Condition.

According to the analysis, the 4-legged roundabout option at the intersection of Sunderland Road at Montague Road operates efficiently under both 2018 and 2038 traffic volume demand. All vehicle queues are anticipated to be accommodated within the available storage. However, the software does not capture the full impact of the interaction between the two study intersections. The forecasted southbound vehicle queues along North Pleasant Street at Meadow Street and Pine Street under both 2018 and 2038 traffic volumes may at times extend back into the roundabout, forcing all circulation at the roundabout to stop.

Alternative 2 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed signal control phasing and timing modifications at the North Pleasant Street at Meadow Street and Pine Street intersection along with the eastbound Meadow Street left turn lane and advance phase would improve the control of heavy turning movement demand. The eastbound Meadow Street approach is projected to experience significantly reduced delay and vehicle queuing under Alternative 2.

Issues:

This control of turning vehicles and subsequent reduction in vehicle conflicts would come at the detriment of other approaches, however, as the proposed timing and phasing modifications would reduce the available percentage of the cycle length attributable to each phase.



Vehicle queueing exceeds available capacity for movements along the northbound, southbound, and westbound approaches to the intersection. The southbound vehicle queues may disrupt traffic flow at the adjacent roundabout proposed at Sunderland Road and Montague Road under this alternative.

Sunderland Road at Montague Road:

Benefits:

The 4-legged roundabout configuration at this intersection is forecast to operate efficiently with no vehicle queuing issues.

Issues:

The roundabout operations may be disrupted by the vehicle queuing at the adjacent study intersection.

5.4.3 Alternative 3

The analysis of Alternative 3 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
 - Install eastbound Meadow Street left turn lane
 - Signal phasing, timing and setting modifications
 - Advanced eastbound phase with southbound right turn overlap movement
 - o Protected northbound and southbound left turn phase
- Sunderland Road at Montague Road
 - Realigned Sunderland Road to intersect Montague Road at a T-type intersection
 - Stop control proposed for Sunderland Road
 - Free operations proposed for Montague Road

Tables 5-12 and 5-13 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-14 and 5-15 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.



Table 5-12 Alternative 3 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.5)	0.26	F (165.4)	1.21	D (38.9)	0.55
	NB	C (25.6)	0.30	F (92.2)	1.05	C (31.5)	0.67
	NBR	A (1.3)	0.02	A (1.1)	0.13	A (1.3)	0.03
	SBL	F (101.6)	0.99	D (45.1)	0.67	F (100.0)	0.98
North Pleasant Street /	SB	F (176.0)	1.29	E (66.9)	0.97	C (30.8)	0.66
Meadow Street / Pine Street	SBR	A (2.2)	0.17	A (2.7)	0.08	A (2.0)	0.19
	EBL	B (13.7)	0.27	C (20.3)	0.62	B (19.4)	0.61
	EB	A (9.4)	0.25	A (8.4)	0.35	A (7.0)	0.26
	WB	B (19.3)	0.67	D (48.2)	0.95	C (25.1)	0.79
	OVERALL	E (65.3)	1.29	E (57.0)	1.21	C (28.8)	0.98
	SWB	A (1.9)	0.22	A (2.0)	0.17	A (1.6)	0.18
Montague Road / Sunderland	SEB	C (20.6)	0.64	E (35.0)	0.88	B (13.2)	0.36
Road	NEB	A (6.0)	0.34	A (8.1)	0.57	A (6.3)	0.43
	OVERALL	A (9.2)	0.64	B (16.5)	0.88	A (6.4)	0.43

Table 5-13 Alternative 3 2018 Intersection Queue Analysis

2018 Build	2018 Build Conditions				Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NBL	100	30 / 49	277 / 452	69 / 113		
	NB	750	77 / 126	393 / 642	172 / 281		
	NBR	100	3/5	17 / 28	4/6		
	SBL	100	163 / 266	89 / 145	166 / 271		
North Pleasant Street / Meadow Street / Pine Street	SB	400	672 / 1,097	338 / 551	146 / 239		
Meddow Street / Time Street	SBR	100	31 / 51	14 / 23	33 / 54		
	EBL	100	39 / 64	90 / 148	83 / 136		
	EB	1,800	61 / 100	87 / 143	65 / 106		
	WB	540	230 / 376	455 / 743	320 / 521		
	SWB	1,200	2/4	3/7	1/3		
Montague Road / Sunderland Road	SEB	1,800	94 / 233	350 / 871	26 / 63		
	NEB	400	24 / 59	125 / 311	45 / 112		



Table 5-14 Alternative 3 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.9)	0.32	F (266.0)	1.47	D (45.1)	0.67
	NB	C (26.2)	0.37	F (177.8)	1.30	D (45.0)	0.85
	NBR	A (1.7)	0.03	A (1.5)	0.17	A (1.7)	0.04
	SBL	F (164.5)	1.20	E (61.6)	0.82	F (163.6)	1.20
North Pleasant Street /	SB	F (294.9)	1.57	F (135.8)	1.19	E (70.2)	0.97
Meadow Street / Pine Street	SBR	A (3.1)	0.22	A (3.0)	0.10	A (3.2)	0.24
	EBL	B (15.5)	0.40	D (35.9)	0.82	F (86.1)	1.03
	EB	B (10.2)	0.30	B (10.3)	0.42	A (8.6)	0.32
	WB	C (27.3)	0.82	F (106.6)	1.18	D (49.4)	0.97
	OVERALL	F (104.5)	1.57	F (106.9)	1.47	D (54.7)	1.20
	SWB	A (2.4)	0.27	A (2.4)	0.21	A (1.9)	0.22
Montague Road / Sunderland	SEB	D (41.1)	0.87	F (122.9)	1.19	B (16.2)	0.49
Road	NEB	A (7.4)	0.43	B (11.6)	0.71	A (8.0)	0.54
	OVERALL	B (16.2)	0.87	D (49.0)	1.19	A (8.1)	0.54

Table 5-15 Alternative 3 2038 Intersection Queue Analysis

2038 Build	2038 Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NBL	100	38/61	439/717	90/ 147		
	NB	750	97/158	672 /1,096	245/400		
	NBR	100	4/7	25/40	5/9		
	SBL	100	271/441	121/198	276/451		
North Pleasant Street / Meadow Street / Pine Street	SB	400	1,046/1,708	601/981	243/397		
meadow offect / Time offect	SBR	100	46/74	18/30	51/83		
	EBL	100	50/81	130/212	176/287		
	EB	1,800	82/134	123/201	88/144		
	WB	540	340/555	684/1,117	532/ 869		
. ,	SWB	1,200	2/6	4/10	2/4		
Montague Road / Sunderland Road	SEB	1,800	202/502	776/ 1,928	48/119		
Nodu	NEB	400	51/128	253/ 630	96/238		

Source: CDM Smith

As shown in Tables 5-12 and 5-14, the traffic signal option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to underserve both the existing and future vehicle demand at the intersection. Approaches forecast to have notably deficient capacity under existing and future traffic conditions are consistent with the No-Build analysis findings and include the southbound North Pleasant Street approach during all study peak hours and the



northbound North Pleasant Street approach during the PM peak hour. The westbound Pine Street approach is forecast to operate at a failing LOS F under the 2038 Build Conditions PM peak hour. The Build Condition installation of the Meadow Street eastbound left turn lane and protected phase, however, is projected to greatly reduce the delay for the eastbound approach from under the 2038 PM and Saturday Midday peak hours. By removing the left turning vehicles which from the eastbound flow, through and right turning eastbound vehicles process through the intersection more efficiently. The increases in delay values at other approaches is due to proposed protected phasing for left turn lanes which reduce vehicle conflicts but detract from available green phase time percentage allocated to all other phases.

As shown in Tables 5-13 and 5-15, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under traffic signal control exceed available storage at many approach movements under existing and future vehicle demand. Approaches forecast to have notably excessive vehicle queue lengths under existing and future traffic conditions includes the southbound North Pleasant Street approach during all study peak hours and the northbound North Pleasant Street approach during the PM peak hour. The westbound queue length under Weekday PM peak hour is forecasted to extend beyond Harris Street, impeding vehicle access to residences. The incorporation of the eastbound left turn lane and protected phasing reduce the No-Build projected queue lengths from distances greater than 1,000 feet to no more than 300 feet under the Build Condition.

According to the analysis, the T-type intersection configuration for Sunderland Road and Montague Road operates sufficiently under both 2018 and 2038 traffic volume demand during the AM and Saturday Midday peak hours. The stop-controlled Sunderland Road approach to the intersection operates at an acceptable LOS D or better under these peak hours. During the PM peak hour, however, the stop-controlled Sunderland Road approach operates at unacceptable LOS E and F under 2018 and 2038 traffic volume demand, respectively. Vehicle queues during the PM peak hour along Sunderland Road under 2038 traffic volumes may extend to Cowls Road and interfere with traffic operations at that intersection. In addition, the northbound vehicle queue along North Pleasant Street towards Sunderland Road may extend to the North Pleasant Street at Meadow Street and Pine Street intersection despite free flow movement. This potential issue is due to the demand of northbound left turning vehicles which must wait for gaps in Montague Road southbound traffic and restrict the northbound through movement traffic.

Alternative 3 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street: Benefits:

The proposed signal control phasing and timing modifications at the North Pleasant Street at Meadow Street and Pine Street intersection along with the eastbound Meadow Street left turn lane and advance phase would improve the control of heavy turning movement demand. The eastbound Meadow Street approach is projected to experience significantly reduced delay and vehicle queuing.



Issues:

This control of turning vehicles and subsequent reduction in vehicle conflicts would come at the detriment of other approaches, however, as the proposed timing and phasing modifications would reduce the available percentage of the cycle length attributable to each phase.

Vehicle queueing exceeds available capacity for movements along the northbound, southbound, and westbound approaches to the intersection. The southbound vehicle queues may disrupt traffic flow at the adjacent roundabout proposed at Sunderland Road and Montague Road under this alternative.

Sunderland Road at Montague Road:

Benefits:

Realigned T-type intersection control may improve driver adherence to traffic control.

Relocating intersection approximately 200 feet north of existing location further separates interaction between the two study intersections.

Issues:

During the PM peak hour vehicles travelling along the stop-controlled Sunderland Road approach are anticipated to experience long delays and vehicle queue lengths extending over 1,000 feet.

Northbound vehicle queues may disrupt traffic operations at the intersection of North Pleasant Street at Meadow Street and Pine Street.

5.4.4 Alternative 4

The analysis of Alternative 4 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
 - Install eastbound Meadow Street left turn lane
 - Signal phasing, timing and setting modifications
 - Advanced eastbound phase with southbound right turn overlap movement
 - Protected northbound and southbound left turn phase
- Sunderland Road at Montague Road
 - Realigned Montague Road to intersect Sunderland Road at a T-type intersection
 - Stop control proposed for Montague Road
 - Free operations proposed for Sunderland Road



Tables 5-16 and 5-17 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-18 and 5-19 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.

Table 5-16 Alternative 4 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.5)	0.26	F (165.4)	1.21	D (38.9)	0.55
	NB	C (25.6)	0.30	F (92.2)	1.05	C (31.5)	0.67
	NBR	A (1.3)	0.02	A (1.1)	0.13	A (1.3)	0.03
	SBL	F (101.6)	0.99	D (45.1)	0.67	F (100.0)	0.98
North Pleasant Street /	SB	F (176.0)	1.29	E (66.9)	0.97	C (30.8)	0.66
Meadow Street / Pine Street	SBR	A (2.2)	0.17	A (2.7)	0.08	A (2.0)	0.19
	EBL	B (13.7)	0.27	C (20.3)	0.62	B (19.4)	0.61
	EB	A (9.4)	0.25	A (8.4)	0.35	A (7.0)	0.26
	WB	B (19.3)	0.67	D (48.2)	0.95	C (25.1)	0.79
	OVERALL	E (65.3)	1.29	E (57.0)	1.21	C (28.8)	0.98
	SB	A (1.8)	0.22	A (1.6)	0.17	A (1.2)	0.14
Montague Road / Sunderland	WB	F (77.3)	0.99	F (57.9)	0.88	F (75.7)	0.98
Road	NB	A (0.0)	0.26	A (0.0)	0.45	A (0.0)	0.45
Course CDM Coulth	OVERALL	C (24.7)	0.99	B (13.2)	0.88	C (20.4)	0.98

Source: CDM Smith

Table 5-17 Alternative 4 2018 Intersection Queue Analysis

2018 Build	2018 Build Conditions				Saturday Peak			
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)					
	NBL	100	30 / 49	277 / 452	69 / 113			
	NB	750	77 / 126	393 / 642	172 / 281			
	NBR	100	3/5	17 / 28	4/6			
	SBL	100	163 / 266	89 / 145	166 / 271			
North Pleasant Street / Meadow Street / Pine Street	SB	400	672 / 1,097	338 / 551	146 / 239			
Meddow Street, Time Street	SBR	100	31 / 51	14 / 23	33 / 54			
	EBL	100	39 / 64	90 / 148	83 / 136			
	EB	1,800	61 / 100	87 / 143	65 / 106			
	WB	540	230 / 376	455 / 743	320 / 521			
	SB	1,700	1/2	1/3	1/1			
Montague Road / Sunderland Road	WB	1,400	200 / 497	112 / 279	180 / 447			
	NB	400	0/0	0/0	0/0			



Table 5-18 Alternative 4 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NBL	D (35.9)	0.32	F (266.0)	1.47	D (45.1)	0.67
	NB	C (26.2)	0.37	F (177.8)	1.30	D (45.0)	0.85
	NBR	A (1.7)	0.03	A (1.5)	0.17	A (1.7)	0.04
	SBL	F (164.5)	1.20	E (61.6)	0.82	F (163.6)	1.20
North Pleasant Street /	SB	F (294.9)	1.57	F (135.8)	1.19	E (70.2)	0.97
Meadow Street / Pine Street	SBR	A (3.1)	0.22	A (3.0)	0.10	A (3.2)	0.24
	EBL	B (15.5)	0.40	D (35.9)	0.82	F (86.1)	1.03
	EB	B (10.2)	0.30	B (10.3)	0.42	A (8.6)	0.32
	WB	C (27.3)	0.82	F (106.6)	1.18	D (49.4)	0.97
	OVERALL	F (104.5)	1.57	F (106.9)	1.47	D (54.7)	1.20
	SB	A (2.3)	0.27	A (2.0)	0.21	A (1.5)	0.17
Montague Road / Sunderland	WB	F (280.3)	1.52	F (227.2)	1.38	F (278.8)	1.51
Road	NB	A (0.0)	0.31	A (0.0)	0.55	A (0.0)	0.55
	OVERALL	F (88.2)	1.52	D (50.7)	1.38	F (74.4)	1.51

Table 5-19 Alternative 4 2038 Intersection Queue Analysis

2038 Build	2038 Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NBL	100	38/61	439/717	90/ 147		
	NB	750	97/158	672 /1,096	245/400		
	NBR	100	4/7	25/40	5/9		
	SBL	100	271/441	121/198	276/451		
North Pleasant Street / Meadow Street / Pine Street	SB	400	1,046/1,708	601/981	243/397		
meddw street, i me street	SBR	100	46/74	18/30	51/83		
	EBL	100	50/81	130/212	176/287		
	EB	1,800	82/134	123/201	88/144		
	WB	540	340/555	684/1,117	532/ 869		
	SB	1,700	2/4	2/5	1/2		
Montague Road / Sunderland Road	WB	1,400	624/ 1,550	426/1,059	583/ 1,449		
	NB	400	0/0	0/0	0/0		

Source: CDM Smith

As shown in Tables 5-16 and 5-18, the traffic signal option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to underserve both the existing and future vehicle demand at the intersection. Similar to Alternatives 1, 2, and 3, approaches forecast to have notably deficient capacity under existing and future traffic conditions are consistent with the No-Build analysis findings and include the southbound North Pleasant Street approach during all



study peak hours and the northbound North Pleasant Street approach during the PM peak hour. The westbound Pine Street approach is forecast to operate at a failing LOS F under the 2038 Build Conditions PM peak hour. By removing the left turning vehicles which from the eastbound flow, through and right turning eastbound vehicles process through the intersection more efficiently. The increases in delay values at other approaches is due to proposed protected phasing for left turn lanes which reduce vehicle conflicts but detract from available green phase time percentage allocated to all other phases.

As shown in Tables 5-17 and 5-19, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under traffic signal control exceed available storage at many approach movements under existing and future vehicle demand. Approaches forecast to have notably excessive vehicle queue lengths under existing and future traffic conditions includes the southbound North Pleasant Street approach during all study peak hours and the northbound North Pleasant Street left turn lane during the PM peak hour. The westbound queue length under Weekday PM peak hour is forecasted to extend beyond Harris Street, impeding vehicle access to residences. The incorporation of the eastbound left turn lane and protected phasing reduce the No-Build projected queue lengths from distances greater than 1,000 feet to no more than 300 feet under the Build Condition.

According to the analysis, the stop-controlled Montague Road approach operates at unacceptable LOS F under 2018 and 2038 traffic volume demand, respectively. Vehicle queues along Montague Road under 2038 traffic volumes may extend to Cowls Road and Summer Street and interfere with traffic operations at those streets. This result is consistent with the No Build analysis for the stop-controlled Montague Road approach. Unlike Alternative 3, under this scenario, the northbound North Pleasant Street is not expected to generate vehicle queue lengths which interfere with the North Pleasant Street at Meadow Street and Pine Street intersection because the approach consists of through and right turn movements only, similar to the Existing and No-Build Conditions.

Alternative 4 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed signal control phasing and timing modifications at the North Pleasant Street at Meadow Street and Pine Street intersection along with the eastbound Meadow Street left turn lane and advance phase would improve the control of heavy turning movement demand. The eastbound Meadow Street approach is projected to experience significantly reduced delay and vehicle queuing.



Issues:

This control of turning vehicles and subsequent reduction in vehicle conflicts would come at the detriment of other approaches, however, as the proposed timing and phasing modifications would reduce the available percentage of the cycle length attributable to each phase.

Vehicle queueing exceeds available capacity for movements along the northbound, southbound, and westbound approaches to the intersection. The southbound vehicle queues may disrupt traffic flow at the adjacent roundabout proposed at Sunderland Road and Montague Road under this alternative.

Sunderland Road at Montague Road:

Benefits:

Realigned T-type intersection control may improve driver adherence to traffic control.

Relocating intersection approximately 200 feet north of existing location further separates interaction between the two study intersections.

The northbound approach of North Pleasant Street to Montague Road consists of through and right turning volumes, minimizing conflicts and delay.

Traffic operations at this intersection are not anticipated to impact the traffic operations at the adjacent study intersection.

Issues:

Vehicles travelling along the stop-controlled Montague Road approach are anticipated to experience long delays and vehicle queue lengths during all peak hours.

5.4.5 Alternative 5

The analysis of Alternative 5 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - Realigned Sunderland Road to intersect Montague Road at a 3-legged roundabout
 - Roundabout excludes adjacent plaza driveway from roundabout control

Tables 5-20 and 5-21 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-22 and 5-23 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.



Table 5-20 Alternative 5 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (4.7)	0.18	B 12.4)	0.65	A (7.2)	0.38
North Pleasant Street /	SB	A (9.9)	0.61	B (11.4)	0.59	A (8.0)	0.49
Meadow Street / Pine Street	EB	A (8.4)	0.37	B (12.2)	0.58	A (7.0)	0.37
(roundabout)	WB	A (4.0)	0.17	A (8.6)	0.44	A (5.9)	0.26
	OVERALL	A (7.5)	0.61	B (11.2)	0.65	A (7.1)	0.49
	SWB	A (7.4)	0.37	A (6.4)	0.26	A (6.0)	0.25
Montague Road / Sunderland Road	SEB	A (9.9)	0.45	A (6.8)	0.31	A (5.8)	0.23
(roundabout)	NEB	A (5.7)	0.32	A (8.6)	0.54	A (7.3)	0.46
, , , , , , , , , , , , , , , , , , , ,	OVERALL	A (7.6)	0.45	A (7.8)	0.54	A (6.7)	0.46

Table 5-21 Alternative 5 2018 Intersection Queue Analysis

2018 Build	Conditions		Weekday A.M. Peak	Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NB	750	10 / 25	86 / 213	23 / 57		
North Pleasant Street / Meadow Street / Pine Street	SB	400	65 / 162	59 / 147	36 / 89		
(roundabout)	EB	1,800	21 / 51	52 / 130	23 / 58		
(WB	540	10 / 24	29 / 71	14 / 35		
Montague Road / Sunderland	SWB	1,200	20 / 50	13 / 32	13 / 31		
Road	SEB	1,800	29 / 73	16 / 40	11 / 27		
(roundabout)	NEB	400	19 / 48	48 / 119	34 / 84		

Source: CDM Smith

Table 5-22 Alternative 5 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (5.5)	0.24	C (27.7)	0.88	B (10.1)	0.51
North Pleasant Street /	SB	B (16.6)	0.79	C (22.7)	0.81	B (11.8)	0.65
Meadow Street / Pine Street	EB	B (12.6)	0.52	C (26.0)	0.82	A (9.6)	0.51
(roundabout)	WB	A (4.7)	0.23	B (13.9)	0.64	A (7.6)	0.36
	OVERALL	B (11.6)	0.79	C (22.9)	0.88	A (9.9)	0.65
	SWB	A (9.1)	0.45	A (8.0)	0.35	A (7.3)	0.33
Montague Road / Sunderland Road	SEB	B (14.0)	0.60	A (8.5)	0.40	A (7.0)	0.30
(roundabout)	NEB	A (6.6)	0.39	B (11.4)	0.67	A (9.0)	0.56
(22 2000)	OVERALL	A (9.8)	0.60	B (10.0)	0.67	A (8.2)	0.56



Table 5-23 Alternative 5 2038 Intersection Queue Analysis

2038 Build	2038 Build Conditions				Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NB	750	13/33	222/551	42/104		
North Pleasant Street / Meadow Street / Pine Street	SB	400	194/ 482	133/329	85/211		
(roundabout)	EB	1,800	38/93	117/290	42/104		
(WB	540	13/32	53/132	20/49		
Montague Road / Sunderland	SWB	1,200	28/69	17/43	17/42		
Road	SEB	1,800	56/138	22/55	15/37		
(roundabout)	NEB	400	26/65	77/191	50/124		

As shown in Tables 5-20 and 5-22, the roundabout option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to serve both the existing and future vehicle demand at the intersection with all approaches operating at LOS C or better.

As shown in Tables 5-21 and 5-23, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under the roundabout option are all accommodated within the available storage with the exception of the southbound approach 95th percentile queue during the AM peak. This vehicle queue may interact with the adjacent Sunderland Road at Montague Road intersection operations.

According to the analysis, similar to Alternative 1, the 3-legged roundabout option at the intersection of Sunderland Road at Montague Road operates efficiently under both 2018 and 2038 traffic volume demand. All vehicle queues are anticipated to be accommodated within the available storage. The 3-legged roundabout at Sunderland Road at Montague Road is not anticipated to impact operations at the intersection of North Pleasant Street at Meadow Street and Pine Street.

Alternative 5 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed roundabout at the North Pleasant Street at Meadow Street and Pine Street intersection is forecasted to process both 2018 and 2038 traffic demand and high turning movement composition with acceptable Level of Service during all peak hours.

Issues:

Vehicle queueing may exceed available capacity for movements along the southbound approach to the intersection during the AM peak hour under 2038 traffic volume demand. This vehicle queue may disrupt traffic flow at the adjacent roundabout proposed at Sunderland Road and Montague Road.



Sunderland Road at Montague Road:

Benefits:

The 3-legged roundabout configuration at this intersection is forecast to operate efficiently with no vehicle queuing issues.

Issues:

The roundabout operations may be disrupted by the vehicle queuing at the adjacent study intersection.

5.4.6 Alternative 6

The analysis of Alternative 6 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - Realigned Sunderland Road to intersect Montague Road at a 4-legged roundabout
 - Roundabout incorporates adjacent plaza driveway into roundabout control

Tables 5-24 and 5-25 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-26 and 5-27 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.

Table 5-24 Alternative 6 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (4.7)	0.18	B 12.4)	0.65	A (7.2)	0.38
North Pleasant Street /	SB	A (9.9)	0.61	B (11.4)	0.59	A (8.0)	0.49
Meadow Street / Pine Street	EB	A (8.4)	0.37	B (12.2)	0.58	A (7.0)	0.37
(roundabout)	WB	A (4.0)	0.17	A (8.6)	0.44	A (5.9)	0.26
	OVERALL	A (7.5)	0.61	B (11.2)	0.65	A (7.1)	0.49
	NWB	A (7.5)	0.37	A (6.7)	0.28	A (6.3)	0.27
Montague Road / Sunderland	SWB	B (10.0)	0.46	B (13.1)	0.64	A (6.3)	0.26
Road (roundabout)	SEB	A (5.1)	0.27	A (8.5)	0.53	A (6.8)	0.43
	NEB	A (4.9)	0.11	A (7.3)	0.16	A (6.1)	0.14
	OVERALL	A (7.4)	0.46	A (9.8)	0.64	A (6.5)	0.43



Table 5-25 Alternative 6 2018 Intersection Queue Analysis

2018 Build	2018 Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NB	750	10 / 25	86 / 213	23 / 57		
North Pleasant Street / Meadow Street / Pine Street (roundabout)	SB	400	65 / 162	59 / 147	36 / 89		
	EB	1,800	21 / 51	52 / 130	23 / 58		
(,	WB	540	10 / 24	29 / 71	14 / 35		
	NWB	20	20 / 50	13 / 33	14 / 34		
Montague Road / Sunderland Road	SWB	1,200	30 / 75	80 / 198	13 / 31		
(roundabout)	SEB	1,800	15 / 38	46 / 113	31 / 76		
(22 3.0000)	NEB	400	5 / 12	7 / 17	6 / 14		

Table 5-26 Alternative 6 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (5.5)	0.24	C (27.7)	0.88	B (10.1)	0.51
North Pleasant Street /	SB	B (16.6)	0.79	C (22.7)	0.81	B (11.8)	0.65
Meadow Street / Pine Street	EB	B (12.6)	0.52	C (26.0)	0.82	A (9.6)	0.51
(roundabout)	WB	A (4.7)	0.23	B (13.9)	0.64	A (7.6)	0.36
	OVERALL	B (11.6)	0.79	C (22.9)	0.88	A (9.9)	0.65
	NWB	A (5.6)	0.15	A (9.4)	0.24	A (7.5)	0.19
Montague Road / Sunderland	SWB	A (9.7)	0.48	A (8.4)	0.36	A (7.8)	0.36
Road (roundabout)	SEB	B (14.9)	0.62	C (24.6)	0.84	A (7.8)	0.34
	NEB	A (5.8)	0.33	B (11.2)	0.66	A (8.2)	0.52
	OVERALL	A (9.9)	0.62	C (15.6)	0.84	A (8.0)	0.52

Source: CDM Smith

Table 5-27 Alternative 6 2038 Intersection Queue Analysis

2038 Build	2038 Build Conditions			Weekday P.M. Peak	Saturday Peak	
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)			
	NB	750	13/33	222/551	42/104	
North Pleasant Street / Meadow Street / Pine Street	SB	400	194/ 482	133/329	85/211	
(roundabout)	EB	1,800	38/93	117/290	42/104	
(**************************************	WB	540	13/32	53/132	20/49	
	NWB	20	6/16	10/24	8/19	
Montague Road / Sunderland Road	SWB	1,200	33/82	19/46	19/47	
(roundabout)	SEB	1,800	59/146	196/487	17/43	
	NEB	400	20/50	73/181	44/110	



As shown in Tables 5-24 and 5-26, the roundabout option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to serve both the existing and future vehicle demand at the intersection with all approaches operating at LOS C or better.

As shown in Tables 5-25 and 5-27, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under the roundabout option are all accommodated within the available storage with the exception of the southbound approach 95th percentile queue during the AM peak. This vehicle queue may interact with the adjacent Sunderland Road at Montague Road intersection operations.

According to the analysis, similar to Alternative 2, the 4-legged roundabout option at the intersection of Sunderland Road at Montague Road operates efficiently under both 2018 and 2038 traffic volume demand. All vehicle queues are anticipated to be accommodated within the available storage. The 4-legged roundabout at Sunderland Road at Montague Road is not anticipated to impact operations at the intersection of North Pleasant Street at Meadow Street and Pine Street.

Alternative 6 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed roundabout at the North Pleasant Street at Meadow Street and Pine Street intersection is forecasted to process both 2018 and 2038 traffic demand and high turning movement composition with acceptable Level of Service during all peak hours.

Issues:

Vehicle queueing may exceed available capacity for movements along the southbound approach to the intersection during the AM peak hour under 2038 traffic volume demand. This vehicle queue may disrupt traffic flow at the adjacent roundabout proposed at Sunderland Road and Montague Road.

Sunderland Road at Montague Road:

Benefits:

The 4-legged roundabout configuration at this intersection is forecast to operate efficiently with no vehicle queuing issues.

<u>Issues:</u>

The roundabout operations may be disrupted by the vehicle queuing at the adjacent study intersection.

5.4.7 Alternative 7

The analysis of Alternative 7 assumes the following intersection improvements:

North Pleasant Street at Meadow Street and Pine Street



- Roundabout control
- Sunderland Road at Montague Road
 - Realigned Sunderland Road to intersect Montague Road at a T-type intersection
 - Stop control proposed for Sunderland Road
 - Free operations proposed for Montague Road

Tables 5-28 and 5-29 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-30 and 5-31 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.

Table 5-28 Alternative 7 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (4.7)	0.18	B 12.4)	0.65	A (7.2)	0.38
North Pleasant Street /	SB	A (9.9)	0.61	B (11.4)	0.59	A (8.0)	0.49
Meadow Street / Pine Street	EB	A (8.4)	0.37	B (12.2)	0.58	A (7.0)	0.37
(roundabout)	WB	A (4.0)	0.17	A (8.6)	0.44	A (5.9)	0.26
	OVERALL	A (7.5)	0.61	B (11.2)	0.65	A (7.1)	0.49
	SWB	A (1.9)	0.22	A (2.0)	0.17	A (1.6)	0.18
Montague Road / Sunderland	SEB	C (20.6)	0.64	E (35.0)	0.88	B (13.2)	0.36
Road	NEB	A (6.0)	0.34	A (8.1)	0.57	A (6.3)	0.43
	OVERALL	A (9.2)	0.64	B (16.5)	0.88	A (6.4)	0.43

Source: CDM Smith

Table 5-29 Alternative 7 2018 Intersection Queue Analysis

2018 Build	2018 Build Conditions				Saturday Peak	
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)			
	NB	750	10 / 25	86 / 213	23 / 57	
North Pleasant Street / Meadow Street / Pine Street	SB	400	65 / 162	59 / 147	36 / 89	
(roundabout)	EB	1,800	21 / 51	52 / 130	23 / 58	
(WB	540	10 / 24	29 / 71	14 / 35	
	SWB	1,200	2/4	3/7	1/3	
Montague Road / Sunderland Road	SEB	1,800	94 / 233	350 / 871	26 / 63	
	NEB	400	24 / 59	125 / 311	45 / 112	



Table 5-30 Alternative 7 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (5.5)	0.24	C (27.7)	0.88	B (10.1)	0.51
North Pleasant Street /	SB	C (16.6)	0.79	C (22.7)	0.81	B (11.8)	0.65
Meadow Street / Pine Street	EB	B (12.6)	0.52	C (26.0)	0.82	A (9.6)	0.51
(roundabout)	WB	A (4.7)	0.23	B (13.9)	0.64	A (7.6)	0.36
	OVERALL	B (11.6)	0.79	C (22.9)	0.88	A (9.9)	0.65
	SWB	A (2.4)	0.27	A (2.4)	0.21	A (1.9)	0.22
Montague Road / Sunderland Road	SEB	E (41.1)	0.87	F (122.9)	1.19	C (16.2)	0.49
	NEB	A (7.4)	0.43	B (11.6)	0.71	A (8.0)	0.54
	OVERALL	B (16.2)	0.87	D (49.0)	1.19	A (8.1)	0.54

Table 5-31 Alternative 7 2038 Intersection Queue Analysis

2038 Build	2038 Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NB	750	13/33	222/551	42/104		
North Pleasant Street / Meadow Street / Pine Street	SB	400	194/ 482	133/329	85/211		
(roundabout)	EB	1,800	38/93	117/290	42/104		
,	WB	540	13/32	53/132	20/49		
	SWB	1,200	2/6	4/10	2/4		
Montague Road / Sunderland Road	SEB	1,800	202/502	776/ 1,928	48/119		
	NEB	400	51/128	253/ 630	96/238		

Source: CDM Smith

As shown in Tables 5-28 and 5-30, the roundabout option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to serve both the existing and future vehicle demand at the intersection with all approaches operating at LOS C or better.

As shown in Tables 5-29 and 5-31, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under the roundabout option are all accommodated within the available storage with the exception of the southbound approach 95th percentile queue during the AM peak. This vehicle queue may interact with the adjacent Sunderland Road at Montague Road intersection operations.

According to the analysis, the T-type intersection configuration for Sunderland Road and Montague Road operates sufficiently under both 2018 and 2038 traffic volume demand during the AM and Saturday Midday peak hours. The stop-controlled Sunderland Road approach to the intersection operates at an acceptable LOS D or better under these peak hours. During the PM peak hour, however, the stop-controlled Sunderland Road approach operates at unacceptable LOS E and F under 2018 and 2038 traffic volume demand, respectively. Vehicle queues during the



PM peak hour along Sunderland Road under 2038 traffic volumes may extend to Cowls Road and interfere with traffic operations at that intersection. In addition, the northbound vehicle queue along North Pleasant Street towards Sunderland Road may extend to the North Pleasant Street at Meadow Street and Pine Street intersection despite free flow movement. This potential issue is due to the demand of northbound left turning vehicles which must wait for gaps in Montague Road southbound traffic and restrict the northbound through movement traffic.

Alternative 7 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed roundabout at the North Pleasant Street at Meadow Street and Pine Street intersection is forecasted to process both 2018 and 2038 traffic demand and high turning movement composition with acceptable Level of Service during all peak hours.

Issues:

Vehicle queueing may exceed available capacity for movements along the southbound approach to the intersection during the AM peak hour under 2038 traffic volume demand. This vehicle queue may disrupt traffic flow at the adjacent Sunderland Road and Montague Road intersection.

Sunderland Road at Montague Road:

Benefits:

Realigned T-type intersection control may improve driver adherence to traffic control.

Relocating intersection approximately 200 feet north of existing location further separates interaction between the two study intersections.

Issues:

During the PM peak hour vehicles travelling along the stop-controlled Sunderland Road approach are anticipated to experience long delays and vehicle queue lengths extending over 1,000 feet.

Northbound vehicle queues may disrupt traffic operations at the intersection of North Pleasant Street at Meadow Street and Pine Street during the PM peak hour under 2038 traffic demand.

5.4.8 Alternative 8

The analysis of Alternative 8 assumes the following intersection improvements:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - Realigned Montague Road to intersect Sunderland Road at a T-type intersection
 - Stop control proposed for Montague Road



• Free operations proposed for Sunderland Road

Tables 5-32 and 5-33 depict the Build Conditions capacity and queue analysis, respectively, under 2018 traffic volumes. Tables 5-34 and 5-35 depict the Build Conditions capacity and queue analysis, respectively, under 2038 traffic volumes.

Table 5-32 Alternative 8 2018 Intersection Capacity Analysis

2018 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (4.7)	0.18	B 12.4)	0.65	A (7.2)	0.38
North Pleasant Street /	SB	A (9.9)	0.61	B (11.4)	0.59	A (8.0)	0.49
Meadow Street / Pine Street	EB	A (8.4)	0.37	B (12.2)	0.58	A (7.0)	0.37
(roundabout)	WB	A (4.0)	0.17	A (8.6)	0.44	A (5.9)	0.26
	OVERALL	A (7.5)	0.61	B (11.2)	0.65	A (7.1)	0.49
	NB	A (1.8)	0.22	A (1.6)	0.17	A (1.2)	0.14
Montague Road / Sunderland	WB	F (77.3)	0.99	F (57.9)	0.88	F (75.7)	0.98
Road	SB	A (0.0)	0.26	A (0.0)	0.45	A (0.0)	0.45
	OVERALL	C (24.7)	0.99	B (13.2)	0.88	C (20.4)	0.98

Source: CDM Smith

Table 5-33 Alternative 8 2018 Intersection Queue Analysis

2018 Build	2018 Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
	NB	750	10 / 25	86 / 213	23 / 57		
North Pleasant Street / Meadow Street / Pine Street	SB	400	65 / 162	59 / 147	36 / 89		
(roundabout)	EB	1,800	21 / 51	52 / 130	23 / 58		
,	WB	540	10 / 24	29 / 71	14 / 35		
	NB	400	1/2	1/3	1/1		
Montague Road / Sunderland Road	WB	1,400	200 / 497	112 / 279	180 / 447		
	SB	1,700	0/0	0/0	0/0		



Table 5-34 Alternative 8 2038 Intersection Capacity Analysis

2038 Build Conditions		Weekday A.M. Peak		Weekday P.M. Peak		Saturday Peak	
Intersection	Movement	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio	LOS (Delay)	V/C Ratio
	NB	A (5.5)	0.24	D (27.7)	0.88	B (10.1)	0.51
North Pleasant Street /	SB	C (16.6)	0.79	C (22.7)	0.81	B (11.8)	0.65
Meadow Street / Pine Street	EB	B (12.6)	0.52	D (26.0)	0.82	A (9.6)	0.51
(roundabout)	WB	A (4.7)	0.23	B (13.9)	0.64	A (7.6)	0.36
	OVERALL	B (11.6)	0.79	C (22.9)	0.88	A (9.9)	0.65
	NB	A (0.0)	0.31	A (0.0)	0.55	A (0.0)	0.55
Montague Road / Sunderland	WB	F (280.3)	1.52	F (227.2)	1.38	F (278.8)	1.51
Road	SB	A (2.3)	0.27	A (2.0)	0.21	A (1.5)	0.17
	OVERALL	F (88.2)	1.52	D (50.7)	1.38	E (74.4)	1.51

Table 5-35 Alternative 8 2038 Intersection Queue Analysis

2038 Build	2038 Build Conditions			Weekday P.M. Peak	Saturday Peak		
Intersection	Movement	Available Storage (ft)	50 th /95 th Percentile Queue Length (ft)				
_	NB	750	13/33	222/551	42/104		
North Pleasant Street / Meadow Street / Pine Street	SB	400	194/ 482	133/329	85/211		
(roundabout)	EB	1,800	38/93	117/290	42/104		
(WB	540	13/32	53/132	20/49		
	NB	400	0/0	0/0	0/0		
Montague Road / Sunderland Road	WB	1,400	624/ 1,550	426/1,059	583/ 1,449		
	SB	1,700	2/4	2/5	1/2		

Source: CDM Smith

As shown in Tables 5-32 and 5-34, the roundabout option of the North Pleasant Street at Meadow Street and Pine Street intersection is forecast to serve both the existing and future vehicle demand at the intersection with all approaches operating at LOS C or better.

As shown in Tables 5-33 and 5-35, the forecasted vehicle queue lengths at the North Pleasant Street at Meadow Street and Pine Street intersection under the roundabout option are all accommodated within the available storage with the exception of the southbound approach 95th percentile queue during the AM peak. This vehicle queue may interact with the adjacent Sunderland Road at Montague Road intersection operations.

According to the analysis, the stop-controlled Montague Road approach operates at unacceptable LOS F under 2018 and 2038 traffic volume demand, respectively. Vehicle queues along Montague Road under 2038 traffic volumes may extend to Cowls Road and Summer Street and interfere with traffic operations at those streets. This result is consistent with the No Build analysis for the stop-controlled Montague Road approach. Unlike Alternative 7, under this scenario, the northbound North Pleasant Street is not expected to generate vehicle queue lengths which



interfere with the North Pleasant Street at Meadow Street and Pine Street intersection due to the fact that the approach consists of through and right turn movements only, similar to the Existing and No-Build Conditions.

Alternative 8 Evaluation Summary:

North Pleasant Street at Meadow Street and Pine Street:

Benefits:

The proposed roundabout at the North Pleasant Street at Meadow Street and Pine Street intersection is forecasted to process both 2018 and 2038 traffic demand and high turning movement composition with acceptable Level of Service during all peak hours.

Issues:

Vehicle queueing may exceed available capacity for movements along the southbound approach to the intersection during the AM peak hour under 2038 traffic volume demand. This vehicle queue may disrupt traffic flow at the adjacent roundabout Sunderland Road and Montague Road intersection.

Sunderland Road at Montague Road:

Benefits:

Realigned T-type intersection control may improve driver adherence to traffic control.

Relocating intersection approximately 200 feet north of existing location further separates interaction between the two study intersections.

The northbound approach of North Pleasant Street to Montague Road consists of through and right turning volumes, minimizing conflicts and delay.

Traffic operations at this intersection are not anticipated to impact the traffic operations at the adjacent study intersection.

Issues:

Vehicles travelling along the stop-controlled Montague Road approach are anticipated to experience long delays and vehicle queue lengths during all peak hours.



Section 6

Recommendations

The Town of Amherst, Massachusetts, has commissioned previous studies to evaluate potential traffic control improvements at the intersections of North Pleasant Street at Pine Street and Meadow Street and Sunderland Road at Montague Road.

This study supplements the previous studies by evaluating multiple permutations of traffic control options at each intersection.

The following traffic control options were considered for the intersection of North Pleasant Street at Pine Street and Meadow Street:

- Traffic control signal upgrade
 - Install eastbound Meadow Street left turn lane
- Roundabout

The following traffic control options were considered for the intersection of Sunderland Road at Montague Road:

- Realign Sunderland Road to create a T-type intersection with Montague Road
 - Stop control for Sunderland Road approach
- Realign Montague Road to create a T-type intersection with Sunderland Road
 - Stop control for Montague Road approach
- 3-Legged Roundabout
 - Roundabout excludes adjacent plaza driveway from roundabout control
- 4-Legged Roundabout
 - Roundabout incorporates adjacent plaza driveway into roundabout control

CDM Smith performed the following tasks to conduct this evaluation:

- This study used 2010, 2013, 2016 and 2017 traffic data to project turning movement counts at the study locations to the year 2018 to represent Existing Conditions traffic volumes.
- Developed year 2038 Future No-Build Conditions traffic volumes based on the recommended 1.0% annual growth rate, traffic associated with other developments, and existing traffic volumes.



- Developed year 2038 Future Build Conditions traffic volumes for all traffic control improvement options based on the Future Conditions traffic volumes and the redistribution of traffic volumes anticipated with the intersection reconfigurations.
- Conducted preliminary roundabout analysis for both study intersections to determine likely approach and circulating lane configurations.
- Conducted capacity analyses for the Existing and Future Conditions with and without improvements.
- Evaluated each construction alternative based on the completed analysis.

The construction alternatives analyzed consisted of the following combinations of the traffic control options at each intersection:

Alternative 1:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
- Sunderland Road at Montague Road
 - 3-legged roundabout

Alternative 2:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
- Sunderland Road at Montague Road
 - 4-legged roundabout

Alternative 3:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
- Sunderland Road at Montague Road
 - Sunderland Road T-type intersection at Montague Road

Alternative 4:

- North Pleasant Street at Meadow Street and Pine Street
 - Traffic control signal upgrade
- Sunderland Road at Montague Road
 - Montague Road T-type intersection at Sunderland Road



Alternative 5:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - 3-legged roundabout

Alternative 6:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - 4-legged roundabout

Alternative 7:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - Sunderland Road T-type intersection at Montague Road

Alternative 8:

- North Pleasant Street at Meadow Street and Pine Street
 - Roundabout control
- Sunderland Road at Montague Road
 - Montague Road T-type intersection at Sunderland Road

Based on preliminary analysis of the roundabout configurations at each intersection, the following configurations were analyzed:

- North Pleasant Street at Pine Street and Meadow Street:
 - Two lane entry for northbound, southbound and westbound approaches
 - Westbound bypass lane
 - Two circulating lanes to receive northbound and southbound multi-lane approaches
- Sunderland Road at Montague Road:
 - Single lane entry for all approaches



Single circulating lane

Upon further analysis using Sidra software and Town of Amherst driver characteristics as described in Section 5.4 Build Condition Alternative Analysis, CDM Smith determined that the roundabout configuration at the North Pleasant Street at Pine Street and Meadow Street intersection could be modified to reduce the number of circulating and entry lanes. Subsequent analysis showed that the preferred roundabout configuration at this location consisted of a single circulating lane and single lane entry for all approaches except the westbound approach which would consist of a standard entry lane and a right turn bypass lane.

Section 5 details the benefits and issues of each construction alternative. Based on the analysis of each construction alternative conducted in this study, the overall expected performance of each traffic control option at each location can be summarized as follows:

North Pleasant Street at Pine Street and Meadow Street:

- Traffic control signal upgrade (Alternatives 1 through 4)
 - Benefits:
 - The proposed signal control phasing and timing modifications at the North Pleasant Street at Meadow Street and Pine Street intersection along with the eastbound Meadow Street left turn lane and advance phase would improve the control of heavy turning movement demand. The eastbound Meadow Street approach is projected to experience significantly reduced delay and vehicle queuing.
 - Issues:
 - This control of turning vehicles and subsequent reduction in vehicle conflicts would come at the detriment of other approaches, however, as the proposed timing and phasing modifications would reduce the available percentage of the cycle length attributable to each phase.
 - o Poor Level of Service forecasted for northbound and southbound approaches under 2018 and 2038 traffic demand. Poor Level of Service forecasted for westbound approach under 2038 traffic demand.
 - o Vehicle queueing exceeds available capacity for movements along the northbound, southbound, and westbound approaches to the intersection. The southbound vehicle queues may disrupt traffic flow at the adjacent Sunderland Road and Montague Road intersection.
- Roundabout (Alternatives 5 through 8)
 - Benefits:
 - o The proposed single lane roundabout at the North Pleasant Street at Meadow Street and Pine Street intersection is forecasted to process both 2018 and 2038 traffic demand and high turning movement composition with acceptable Level of Service during all peak hours.
 - Issues:



 Vehicle queueing may exceed available capacity for movements along the southbound approach to the intersection during the AM peak hour under 2038 traffic volume demand. This vehicle queue may disrupt traffic flow at the adjacent Sunderland Road and Montague Road intersection.

Sunderland Road at Montague Road

- 3-legged roundabout (Alternatives 1 and 5)
 - Benefits:
 - o The 3-legged roundabout configuration at this intersection is forecast to operate efficiently with no vehicle queuing issues.
 - Issues:
 - The roundabout operations may be disrupted by the vehicle queuing at the adjacent study intersection. The traffic control signal option at the adjacent study intersection is forecasted to produce larger vehicle queue lengths and have greater impact to the Sunderland Road at Montague Road intersection than the roundabout option.
- 4-legged roundabout (Alternatives 2 and 6)
 - Benefits:
 - The 4-legged roundabout configuration at this intersection is forecast to operate efficiently with no vehicle queuing issues.
 - Issues:
 - The roundabout operations may be disrupted by the vehicle queuing at the adjacent study intersection. The traffic control signal option at the adjacent study intersection is forecasted to produce larger vehicle queue lengths and have greater impact to the Sunderland Road at Montague Road intersection than the roundabout option.
- Sunderland Road T-type intersection at Montague Road (Alternatives 3 and 7)
 - Benefits:
 - Realigned T-type intersection control may improve driver adherence to traffic control.
 - o Relocating intersection approximately 200 feet north of existing location further separates interaction between the two study intersections.
 - Issues:
 - O During the PM peak hour vehicles travelling along the stop-controlled Sunderland Road approach are anticipated to experience long delays and large vehicle queue lengths.



- o Northbound vehicle queues may disrupt traffic operations at the intersection of North Pleasant Street at Meadow Street and Pine Street.
- Montague Road T-type intersection at Sunderland Road (Alternatives 4 and 8)
 - Benefits:
 - Realigned T-type intersection control may improve driver adherence to traffic control.
 - Relocating intersection approximately 200 feet north of existing location further separates interaction between the two study intersections.
 - o The northbound approach of North Pleasant Street to Montague Road consists of through and right turning volumes, minimizing conflicts and delay.
 - o Traffic operations at this intersection are not anticipated to impact the traffic operations at the adjacent study intersection.
 - Issues:
 - Vehicles travelling along the stop-controlled Montague Road approach are anticipated to experience long delays and vehicle queue lengths during all peak hours.

The analysis result of the traffic control signal operation at the intersection of North Pleasant Street at Pine Street and Meadow Street forecasting poor performance contrasts the expected efficient performance of an upgraded traffic control signal as defined in the 2015 evaluation conducted by CDM Smith. As mentioned under Section 3.4 Existing Traffic Volumes, the composition of turning movement demand versus through travel demand at this intersection changed considerably from 2013 to 2017 during the PM peak period. Despite proposed phasing improvements to better control turning movement demand at this intersection, the relatively balanced demand at each approach recorded in the updated traffic data is too high for each approach to be served efficiently.

Final Recommendation

A comparison of expected operational performance between the two traffic control options at the intersection of North Pleasant Street at Pine Street and Meadow Street indicates that the roundabout option (Alternatives 5-8) will process the vehicle demand and high turning movement composition at the intersection more efficiently than the traffic control signal option (Alternatives 1-4). The roundabout option is anticipated to provide less vehicle delay and smaller vehicle queue lengths. The roundabout option would also have less impact to traffic operations at the adjacent study intersection. The impact to private property to accommodate the roundabout will need to be assessed to determine if the roundabout with the requisite westbound right turn slip lane is fully feasible.

At the intersection of Sunderland and Montague Roads, the stop-controlled approaches at the T-type intersection options (Sunderland Road under Alternatives 3 and 7; Montague Road under Alternatives 4 and 8) are expected to experience long delays and large vehicle queue lengths.



Additionally, the stop-controlled Sunderland Road T-type intersection option may impact operations at the adjacent study intersection due to the large northbound approach left turn demand onto Sunderland Road restricting through vehicles while waiting for a gap in southbound traffic.

The 3-legged roundabout (Alternatives 1 and 5) and 4-legged roundabout (Alternatives 2 and 6) are forecasted to serve all approaches efficiently. The roundabout flow efficiency at Sunderland Road and Montague Road, however, is contingent upon the southbound approach at the intersection of North Pleasant Street at Pine Street and Meadow Street processing efficiently without vehicle queues extending into the roundabout. Southbound approach queue lengths associated with the proposed roundabout are anticipated to be smaller than those associated with the traffic control signal option.

Based on the analysis and summary of benefits and issues associated with each traffic control option, Alternative 5 (roundabout at North Pleasant Street/Meadow Street/Pine Street; 3-legged roundabout at Sunderland Road/Montague Road) and Alternative 6 (roundabout at North Pleasant Street/Meadow Street/Pine Street; 4-legged roundabout at Sunderland Road/Montague Road) are forecast to provide the most efficient control of traffic at the study intersections. Alternatives 5 and 6 are also forecast to provide the least disruptive interaction between the two study intersections.

The added benefit of the 4-legged roundabout included in Alternative 6 is that the adjacent plaza access can be incorporated directly into the roundabout control. The 3-legged roundabout option included in Alternative 5 may restrict full access to the plaza drives depending on the final roundabout location relative to the plaza drives and the design of the splitter islands along approaches. It is possible that access to the plaza from the north may only be possible by entering the roundabout circulation and then traveling northbound to enter the plaza via right turn at the northern plaza drive.

The location of the 4-legged roundabout may also be further north than the 3-legged roundabout in order to incorporate the plaza drive into the roundabout control. Therefore, the distance between the 4-legged roundabout and Meadow Street/Pine Street under Alternative 6 may be slightly larger than the distance between the 3-legged roundabout and Meadow Street/Pine Street under Alternative 5. By increasing the distance between the intersections, the available queueing distance for the southbound North Pleasant Street approach is also increased, reducing potential interactions between the intersections.

Due to the anticipated traffic operations, access to the private plaza drives, and potentially reduced interactions between the study intersections, CDM Smith recommends Alternative 6: a single lane roundabout with a westbound right turn bypass lane at the intersection of North Pleasant Street at Meadow Street and Pine Street complemented by a 4-legged roundabout at the intersection of Sunderland Road at Montague Road which incorporates private plaza access into the roundabout control.



